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Technical Reference  
TR-NWT-000332  
Issue 3, September 1990

# Reliability Prediction Procedure for Electronic Equipment

A Module of RQGR, TR-TSY-000796

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This document replaces:

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Reliability Prediction  
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## 1. INTRODUCTION

### 1.1 Purpose and Scope

A prediction of reliability is an important element in the process of selecting equipment for use by the Bellcore Client Companies (BCCs). As used here, reliability is a measure of the frequency of equipment failures as a function of time. Reliability has a major impact on maintenance and repair costs and on the continuity of service.

The purpose of this procedure is to document the recommended methods for predicting device<sup>1</sup> and unit<sup>2</sup> hardware<sup>3</sup> reliability. This procedure also documents the recommended method for predicting serial system<sup>4</sup> hardware reliability.<sup>5</sup> It contains instructions for suppliers to follow when providing predictions of their device, unit, or serial system reliability (hereafter called "product" reliability). It also can be used directly by the BCCs for product reliability evaluation.

Device and unit failure rate predictions generated using this procedure are applicable for commercial electronic products whose physical design, manufacture, installation, and reliability assurance practices meet the appropriate Bellcore (or equivalent) generic and product-specific requirements.

This procedure cannot be used directly to predict the reliability of a non-serial system. However, the unit reliability predictions resulting from application of this procedure can be input into system reliability models for prediction of system level hardware reliability parameters.

Currently, this procedure also includes some discussion of system level operating and configuration information that may affect overall system reliability. The procedure directs the requesting organization to compile this information in cases where the unit level reliability predictions are computed for input to a specific system reliability model. This system level information is not directly necessary for computation of the unit level

- 
1. "Device" refers to a basic component (or part) listed in Table A of this document:
  2. "Unit" is used herein to describe any customer replaceable assembly of devices. This may include, but is not limited to, circuit packs, modules, plug-in units, racks, power supplies, and ancillary equipment. Unless otherwise dictated by maintenance considerations, a unit will usually be the lowest level of replaceable assemblies/devices.
  3. The procedure is directed toward unit level failures caused by device hardware failures. Failures due to programming errors on firmware devices are not considered. However, the hardware failure rates of firmware devices are considered.
  4. "Serial system" refers to any system for which the failure of any single unit will cause a failure of the system.
  5. Troubles caused by transient faults, software problems, procedural errors, or unexpected operating environments can have a significant impact on system level reliability. Therefore, system hardware failures represent only a portion of the total system trouble rate.

reliability predictions. but these information requirements are not currently addressed in any other Bellcore requirements document and are therefore included in this reference.

## 1.2 Changes

This issue of the Reliability Prediction Procedure (RPP) includes the following changes from previous issue:

- Change of the RPP Method III procedure, *Statistical Predictions from Field Tracking*.
- Addition of instructions in Table A for computing RPP reliability predictions for Program Array Logic (PAL) and Gate Array devices
- Addition of instructions in Section 6 for computing RPP reliability predictions for device types/technologies not included in Table A
- Revision of device failure rates in Table A
- Revision of some quality factors in Table D for non-hermetic ICs and plastic discrete semiconductor devices
- Addition of an additional item (item "i") in the definition of Quality Level III in Table C
- Adjustment of worked examples to be consistent with the Table A revisions
- Minor changes to the text to improve clarity.

## 2. PURPOSES OF RELIABILITY PREDICTIONS

Unit level reliability predictions derived in accordance with this procedure serve the following purposes:

- Reliability predictions can be used to assess the effect of product reliability on the maintenance activity and on the quantity of spare units required for acceptable field performance of any particular system. For example, predictions of the frequency of unit level maintenance actions can be obtained. Reliability parameters of interest include:

- Steady-state<sup>6</sup> unit failure rate.<sup>7</sup>
  - First Year Multiplier. The average failure rate during the first year of operation (8760 hours) can be expressed as a multiple of the steady-state failure rate, called the *first year multiplier*. The steady-state failure rate provides the information needed for long-term product performance. The first year multiplier, together with the steady-state failure rate, provides a measure of the number of failures expected in the first year of operation.
- Reliability predictions provide necessary input to system level reliability models.<sup>8</sup>
  - Reliability predictions provide necessary input to unit and system level Life Cycle Cost Analyses.
  - Reliability predictions assist in deciding which product to purchase from a list of competing products. As a result, it is essential that reliability predictions be based on a common procedure.
  - Reliability predictions are used to set standards for factory reliability tests.
  - Reliability predictions are used to set standards for field performance.

### 3. GUIDELINES FOR REQUESTING RELIABILITY PREDICTIONS

#### 3.1 Needed Parameters

The requesting organization should determine the uses and purposes of the reliability predictions. Based on these purposes, the requesting organization can specify the desired reliability parameters. In most situations, the supplier will be asked to provide both the steady-state failure rates and the first year multipliers.

- 
6. "Steady-state" is that phase of the product's operating life during which the failure rate is constant. Herein the steady-state phase is assumed preceded by an infant mortality phase characterized by a decreasing failure rate.
  7. Unless stated otherwise, all failure rates herein are expressed as *failures per 10<sup>6</sup> operating hours*, denoted as FITs.
  8. System level reliability models can subsequently be used to predict, for example, frequency of system outages in steady-state, frequency of system outages during early life, expected downtime per year, and system availability.

### 3.2 Choice of Method

This procedure includes three general methods, called Methods I, II, and III, for predicting product reliability. (See Sections 5 through 9 for a description of the methods.) The supplier must provide Method I predictions for all devices or units unless the requesting organization allows otherwise in accordance with Section 4.1.

In addition to the Method I predictions, the supplier may submit predictions calculated using Methods II or III. However, in cases where two or more predictions are submitted for the same device or unit, the requesting organization will determine which prediction is to be used.

### 3.3 Operating Conditions and Environment

Device failure rates vary as a function of operating conditions and environment. The requesting organization should describe the typical operating conditions and physical environment(s) in which the products will operate. This description should include:

- The ambient temperature— in cases where the ambient temperature varies significantly over time, the requesting organization should determine, according to its own needs, the temperature value(s) to provide.
- The environmental classification, as described in Table H— if the product will be exposed to more than one environment class, each should be specified. The environmental multiplying factor for each classification should be entered on the "Request for Reliability Prediction" form (Form 1, Figure 8).

### 3.4 System Level Information

If the reliability predictions are to provide input for predicting reliability parameters for a particular system, then the requesting organization:

- May request predictions for specific system level service-affecting parameters (e.g., frequency of system outage) concurrently with the unit or device reliability predictions. These should be specified on the "Request for Reliability Prediction" form (Form 1, Figure 8).
- Should clearly specify the definition of a failure. This is a crucial element in predicting system reliability parameters. For non-complex equipment, the definition of a failure is usually clear. Faults in complex equipment may distinguish between those affecting maintenance or repair and those affecting service. For example, it is often desirable for multichannel systems to define the maximum number of channels that can be out before the system is considered failed, that is, no longer providing acceptable service.

In addition to overall system reliability objectives, some complex, multi-function systems may have reliability objectives for individual functions or for various states of reduced service capability. For such systems, it may be necessary to develop reliability models to

address these additional objectives. Guidelines for developing these models are outside the scope of this document.

The requesting organization should describe any other system level operating conditions and requirements that may influence reliability. These are to be presented in sufficient detail to preclude significant variations in assumptions on the part of different suppliers. These conditions are likely to be unique for each equipment type. For example, some of the operating conditions affecting reliability predictions for subscriber loop carrier equipment are:

- Temperature and humidity variations
- Single or redundant T1 line facilities
- Distance between terminals
- Duration of commercial power outages
- Lightning induction.

### 3.5 Procedure Verification

On receipt of a completed reliability prediction package, the requesting organization should verify the computations and correct use of the procedure. Any device procurement specifications, circuit design information, field tracking information, test/inspection information, and required worksheets provided in the package should be reviewed for completeness and accuracy.

If the requesting organization desires documentation or information beyond that specified in this procedure, the documentation or information should be requested on the "Request for Reliability Prediction" form (Form 1, Figure 8) or in subsequent correspondence.

This procedure allows a supplier to present additional reliability data, such as operational field data, details concerning maintenance features, design features, burn-in<sup>9</sup> procedures, reliability-oriented design controls and standards, and any other factors important in assessing reliability. This information must be carefully considered by the requesting organization to ensure a meaningful analysis of the supplier's product.

It is the responsibility of the requesting organization to provide the supplier with all relevant details of proposed product use. This will enable the supplier to provide only such additional information as is appropriate to the specific case.

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9. "Burn-in" is defined as any powered operation that fully simulates (with or without acceleration) normal use conditions.

## 4. GUIDELINES FOR THE PREDICTION METHODS

### 4.1 Preferred Methods

This procedure permits use of the best technically supportable evidence of product reliability based on field data, laboratory tests, MIL-HDBK-217,<sup>[1]</sup> device manufacturer's data, unit supplier's data, or engineering analysis. The methods for predicting reliability are:

*Method I:* Predictions are based solely on the "Parts Count" procedure<sup>10</sup> in Sections 5 and 6. This method can be applied to individual devices or units. Unit level parts count predictions can be calculated using Method I, II, or III device level predictions.

*Method II:* Unit or device level statistical predictions are based on combining Method I predictions with data from a laboratory test performed in accordance with the criteria given in Section 7.

*Method III:* Statistical predictions of in-service reliability are based on field tracking data collected in accordance with the criteria given in Section 8.

Although the three methods specified here are preferred, calculation of additional predictions using other technically sound sources of data and/or technically sound engineering techniques is not precluded. Other sources or techniques could include device manufacturer's data, unit supplier's data, reliability physics considerations, extrapolation models, and engineering analysis. This approach may be particularly useful in adjusting Method I estimates for new technology devices where no substantial field data exists. A supplier must fully explain and document the technical basis for any such predictions. In such cases, the requesting organization will then determine whether the RPP or alternate prediction is to be used.

Subject to prior approval from the requesting organization, the supplier may submit Parts Count predictions for a specified subset, rather than for the entire set of devices or units.

### 4.2 Inquiries

Questions regarding the interpretation or use of these methods should be addressed in writing to the organization that requested the reliability prediction. The Switching Technology Analysis and Reliability Center in Bellcore can also provide assistance.

Sections 5 and 6 discuss Method I; Section 7 discusses Method II; and Section 8 discusses Method III.

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10. The "Parts Count" procedure used in this method is based on MIL-HDBK-217.

## 5. OVERVIEW OF METHOD I: PARTS COUNT METHOD

### 5.1 General Description

The prediction technique described in this section is commonly known as a "Parts Count" method. That is, the unit failure rate is assumed to be equal to the sum of the device failure rates. Modifiers are included to account for variations in equipment operating environment, device quality requirements, and device application conditions (e.g., temperature and electrical stress). For application of this method, the possible combinations of burn-in treatment and device application conditions are separated into three cases, which are described below. Unless the requesting organization requires Case 3, the case to be used is at the supplier's discretion.

- Case 1: Black Box option with unit/system burn-in  $\leq 1$  hour and no device burn-in. Devices are assumed to be operating at 40 ° C and 50 percent rated electrical stress.
- Case 2: Black Box option with unit/system burn-in  $> 1$  hour but no device burn-in. Devices are assumed to be operating at 40 ° C and 50 percent rated electrical stress.
- Case 3: General Case — everything else. This case would be used when the supplier wants to take advantage of device burn-in. It would also apply when the supplier wants to use, or the requesting organization requires, reliability predictions that account for operating temperatures or electrical stresses at other than 40 ° C and 50 percent, respectively. These predictions will henceforth be referred to as "limited stress" predictions.

### 5.2 Case Selection

This method is designed so that computation of first year multipliers and steady-state reliability predictions is simplest when there is no burn-in and when the temperature and electrical stress levels are assumed to be 40 ° C and 50 percent, respectively. Thus, the cases are listed above in order of complexity— Case 1 being the simplest. The reason the supplier may opt to use Case 2 is that Case 2 allows for system or unit burn-in time to reduce the failure rate attributed in the infant mortality period. Case 3 (the General Case) allows the use of all types of burn-in to reduce the failure rate attributed in the infant mortality period. The limited stress option, which can only be handled under Case 3, should produce more accurate predictions when the operating temperature and electrical stress do not equal 40 ° C and 50 percent, respectively.

Since it is considerably more time-consuming to perform and verify limited stress predictions, it is recommended that Case 3 be used as the sole prediction method only where ten or fewer unit designs are involved or where a more precise reliability prediction is necessary.

The requesting organization has the option to require the supplier to perform a (sampled) limited stress prediction. In cases where a large number of unit level predictions are to be computed, the following approach may be specified if agreement can be reached with the product supplier:

1. The requesting organization selects a sample of ten unit designs that are representative of the system. The following criteria are to be used in the sample selection process:
  - (a) If any devices are burned-in, select ten unit designs that, on the whole, contain a proportion of these devices consistent with the proportion of burned-in devices in the system.
  - (b) Do not select unit designs for units that are subjected to unit level burn-in. (Predictions for these designs should be computed using the limited stress option. Usually there will be few unit designs in this category.)
  - (c) Include unit designs that are used in large quantities in the system.
  - (d) Include unit designs that perform different functions, for example, power supplies and digital, analog, and memory units.
2. The product supplier performs a limited stress reliability prediction and calculates the first year multiplier ( $\pi_{FY}$ ) for each selected unit design.
3. The product supplier performs a steady-state black box reliability prediction on *all* units (excluding those in item 1b above).
4. The average  $\pi_{FY}$  value determined from the sample in item 2 is applied to all non-sampled unit designs (excluding those in item 1b above).
5. The average ratio between the steady-state black box prediction and steady-state limited stress prediction of the sampled unit designs is applied to all non-sampled designs (excluding those in item 1b above).
6. If the sample adequately represents the total system, this approach will provide a more precise measure of first year and steady-state unit failure rates than is available by the black box option; yet, it will not be as complicated and time-consuming as a limited stress prediction done on every unit design.
7. A word of caution. Care must be used to avoid bias in the sample selection. This is particularly important when system level parameters computed in a system reliability model are to be compared with the system level parameters for a competing system.

When unit level reliability predictions are to be input into system reliability models, whichever case is used must normally be used for all units in the system. Currently, the only exceptions are when:

- The requesting organization specifically requests a deviation.
- Limited stress predictions are required, but detailed device application information is not available for purchased sub-assemblies because of proprietary designs. In such instances, a black box prediction (Case 1 or 2) may be applied to these units.
- A sampled limited stress prediction is required.

### 5.3 Additional Information

Information such as block diagrams, parts lists, procurement specifications, and test requirements may be requested to verify that results presented by the supplier are correct. Some items of this nature are specifically requested in this procedure; additional items may be requested in other documents or letters. If the supplier does not provide the requested information, the worst case assumptions must be used (e.g., if procurement specifications or test/inspection procedures are not provided, the worst quality level will be assumed).

Information required to perform the reliability predictions can be found in the following:

- Section 6 describes the detailed steps to be followed in predicting unit reliability.
- Tables A through J contain the information necessary to determine device and unit failure rates and modifying factors.
- Forms 2 through 12 contain worksheets to be used in reliability prediction.

### 5.4 Operating Temperature Definition

The following definitions apply for selecting temperature factors from Table G to perform Method I predictions. The *unit operating temperature* is determined by placing a temperature probe in the air  $\frac{1}{2}$  inch above (or between) the unit(s) while it is operating under normal conditions.<sup>11</sup> The *device operating temperature* is the unit operating temperature of the unit in which the device resides.

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11. "Normal conditions" refer to the operating conditions for which the reliability prediction is to apply. If the reliability predictions are used as input in a system level reliability model, this will be the operating conditions for the product in that particular system.

## 6. INSTRUCTIONS FOR METHOD I: PARTS COUNT METHOD

### 6.1 Available Options

As described in Section 5.1, there are three cases for the Parts Count Method:

- Case 1 - black box option (assumed operating temperature and electrical stress of 40 °C and 50 percent) with unit/system burn-in  $\leq 1$  hour, no device burn-in
- Case 2 - black box option (assumed operating temperature and electrical stress of 40 °C and 50 percent) with unit/system burn-in  $> 1$  hour, no device burn-in
- Case 3 - General Case.

This section contains the complete formulae and equations for Case 3, and the simplified versions for Cases 1 and 2 for calculating  $\lambda_{SS}$  (the steady state failure rate) and  $\pi_{FY}$  (the first year multiplier).

### 6.2 Steady-State Failure Rate

#### 6.2.1 Device Steady-State Failure Rate

For the general case (Case 3) the *device* steady-state failure rate,  $\lambda_{SS_i}$ , is given by:

$$\lambda_{SS_i} = \lambda_{G_i} \pi_{Q_i} \pi_{S_i} \pi_{T_i} \quad (1)$$

where

- $\lambda_{G_i}$  = generic failure rate for the  $i^{th}$  device (Table A)
- $\pi_{Q_i}$  = quality factor for the  $i^{th}$  device (Table D)
- $\pi_{S_i}$  = stress factor for the  $i^{th}$  device (Tables E and F)
- $\pi_{T_i}$  = temperature factor for the  $i^{th}$  device (Table G) due to normal operating temperature during steady-state.

For Cases 1 and 2, since the temperature and electrical stress factors (Tables F and G) are  $\pi_T = \pi_S = 1.0$  at 40 °C and 50 percent electrical stress for all device types, the formula can be simplified to:

$$\lambda_{SS_i} = \lambda_{G_i} \pi_{Q_i} \quad (2)$$

### 6.2.2 Unit Steady-State Failure Rate

The unit steady-state failure rate prediction,  $\lambda_{SS}$ , is computed as the sum of the device failure rate predictions for all devices in the unit, multiplied by the unit environmental factor:

$$\lambda_{SS} = \pi_E \sum_{i=1}^n N_i \lambda_{SS_i}$$

where

$n$  = number of different device types in the unit

$N_i$  = quantity of  $i^{th}$  device type

$\pi_E$  = unit environmental factor (Table H).

## 6.3 First Year Multipliers

### 6.3.1 Device Effective Burn-in Time

To compute the first year multiplier for the  $i^{th}$  device type, it is necessary to compute a quantity called the effective burn-in time,  $t_{e_i}$ . For *Case 3*:

$$t_{e_i} = \frac{A_{b,d} t_{b,d} + A_{b,u} t_{b,u} + A_{b,s} t_{b,s}}{A_{op} \pi_{s_i}}$$

where

$A_{b,d}$  = Arrhenius acceleration factor (Table G, Curve 7)  
corresponding to the device burn-in temperature

- $t_{b,d}$  = device burn-in time (hours)
- $A_{b,u}$  = Arrhenius acceleration factor (Table G, Curve 7) corresponding to the unit burn-in temperature
- $t_{b,u}$  = unit burn-in time (hours)
- $A_{b,s}$  = Arrhenius acceleration factor (Table G, Curve 7) corresponding to the system burn-in temperature
- $t_{b,s}$  = system burn-in time (hours)
- $A_{op}$  = temperature acceleration factor (Table G, Curve 7) corresponding to normal operating temperature
- $\pi_{S_i}$  = electrical stress factor (Tables E and F) due to normal operating conditions.

*Case 2:* Since there is no device level burn-in and the normal operating temperature and electrical stress are assumed to be 40 °C and 50 percent,  $t_{b,d} = 0.0$ ,  $A_{op} = \pi_{S_i} = 1.0$ , and the formula for effective burn-in time reduces to:

$$t_e = A_{b,u} t_{b,u} + A_{b,s} t_{b,s}$$

*Case 1:* Since unit/system burn-in  $\leq 1$  hour and there is no device burn-in:

$$t_{e_i} = 1.0$$

### 6.3.2 Device First Year Multipliers $\pi_{FY_i}$

*Case 3:*

When device/unit/system burn-in  $> 1$  hour,

- If  $t_{e_i} \geq \frac{10,000}{\pi_{T_i} \pi_{S_i}}$ , then  $\pi_{FY_i} = 1$ .

- If  $\frac{10,000}{\pi_{T_i} \pi_{S_i}} - 8760 < t_{e_i} < \frac{10,000}{\pi_{T_i} \pi_{S_i}}$ , then

$$\pi_{FY_i} = \frac{1.14}{\pi_{T_i} \pi_{S_i}} \left[ \frac{t_{e_i} \pi_{T_i} \pi_{S_i}}{10,000} - 4 \left( \frac{t_{e_i} \pi_{T_i} \pi_{S_i}}{10,000} \right)^{0.25} + 3 \right] + 1.$$

- If  $t_{e_i} \leq \frac{10,000}{\pi_{T_i} \pi_{S_i}} - 8760$ , then

$$\pi_{FY_i} = \frac{0.46}{(\pi_{T_i} \pi_{S_i})^{0.75}} \left( (t_{e_i} + 8760)^{0.25} - t_{e_i}^{0.25} \right)$$

When device/unit/system Burn-in  $\leq 1$  hour,

- If  $10,000 \geq 8760 \pi_{T_i} \pi_{S_i}$ , then

$$\pi_{FY_i} = 4/(\pi_{T_i} \pi_{S_i})^{0.75}.$$

- Otherwise,

$$\pi_{FY_i} = 1 + 3/(\pi_{T_i} \pi_{S_i}).$$

Case 2:

Since  $\pi_{T_i} = \pi_{S_i} = 1.0$  for Case 2, use the following:

- If  $0 < t_{e_i} < 10,000$ , then use the  $\pi_{FY}$  value from Table I.

- If  $t_{e_i} > 10,000$ , then  $\pi_{FY_i} = 1$ .

Case 1:

$$\pi_{FY_i} = 4.0$$

### 6.3.3 Unit First Year Multiplier ( $\pi_{FY}$ )

To obtain the unit first year multiplier, use:

$$\pi_{FY} = \frac{\sum_{i=1}^n (N_i \lambda_{SS_i} \pi_{FY_i})}{\sum_{i=1}^n (N_i \lambda_{SS_i})}$$

## 6.4 Worksheets

- Forms 2 and 3 are worksheets for calculating device and unit failure rates for Case 1.
- Forms 2 and 4 are worksheets for calculating device and unit failure rates for Case 2.
- Forms 5 and 6 are worksheets for calculating device and unit failure rates for the general case, Case 3.

Completed samples of these forms accompany the examples in the following section.

## 6.5 Examples

### 6.5.1 Example 1: Case 1 (Forms 2 and 3)

Assume the unit called EXAMPLE has the following devices:

Device Type	Quantity
IC, Digital, Bipolar, Non-hermetic, 30 gates	10
IC, Digital, NMOS, Non-hermetic, 200 gates	5
Transistor, Si, PNP, Plastic, $\leq 0.6$ W	5
Capacitor, Discrete, Fixed, Ceramic	5
LED, Non-hermetic, 1300 nm	1

Device Quality Level I is assumed for the capacitors and the LED, and Device Quality Level II is assumed for all other devices on the unit. The requesting organization has specified the environmental factor  $\pi_E = 1.5$  (from Table H) on the "Request For Reliability Prediction" form (Form 1, Figure 8).

Assume that the requesting organization does not require a limited stress prediction (Case 3) for the unit EXAMPLE; that is, it is permissible to assume operating conditions of 40 °C temperature and 50 percent electrical stress. Furthermore, there is no device, unit, or system burn-in (or there is burn-in but the manufacturer is not claiming credit for it). Under these conditions, reliability predictions for the unit EXAMPLE are calculated using Forms 2 and 3. Figures 1 and 2 illustrate the completed forms for this example and are shown on the following pages.

#### 6.5.2 Example 2: Case 2 (Forms 2 and 4)

Consider the unit EXAMPLE, from Example 1 (see Section 6.5.1). As in Example 1, assume the requesting organization did not require a limited stress (Case 3) reliability prediction for the unit. However, there is unit burn-in of 72 hours at 70 °C, for which the manufacturer would like to receive credit. Reliability predictions for the unit EXAMPLE should then be calculated using Form 2, as in Example 1, and Form 4. Figures 3 and 4 illustrate completed forms for this example and are shown on the following pages.



## Unit Reliability Prediction Worksheet

Case 1 - Black Box Estimates (50% Stress, Temperature = 40 °C,  
Unit/System Burn-in ≤1 Hour, No Device Burn-in)

[illegible]

Figure 2. Example 1, Case 1 (Worked Form 3)



## Unit Reliability Prediction

### Worksheet

Case 2 - Black Box Estimates (50% Stress, Temperature = 40°C,  
No Device Burn-in, Unit/System Burn-in > 1 Hour)

Date		8/1/88		Page 1 Of 1	
Product		APPARATUS		Rev 1	
Manufacturer		XYZ, Inc.			
Unit name		Example 2			
Unit Number		11-24			
Repair category					
Factory repairable		X			
Field repairable					
Other					
Unit burn-in					
Temperature $T_{b,u}$		70°			
Acceleration factor ‡ $A_{b,u}$		3.7			
Time $t_{b,u}$		72			
System burn-in					
Temperature $T_{b,s}$		NA			
Acceleration factor ‡ $A_{b,s}$		NA			
Time $t_{b,s}$		NA			
Effective burn-in time $t_e$					
$t_e = A_{b,u}t_{b,u} + A_{b,s}t_{b,s}$ (a)		266			
First year Multiplier (Table I)	$\pi_{FY}$	2.6			
$\lambda_{SS}$ (from Figure 2)	$\lambda_{SS}$	2157			
If Method II is applied to units, from Figure 12	$\lambda'_{SS}$	NA			
Comments:					

‡ Obtain From Table G, Curve 7

Figure 4. Example 2, Case 2 (Worked Form 4)

### 6.5.3 Example 3: Case 3, General Case (Forms 5 and 6)

Consider again the unit EXAMPLE, from Example 1. Assume that reliability predictions for the unit EXAMPLE must be calculated using the "Limited Stress" option. The unit operating temperature is 45 °C. All the transistors are operated at 40 percent electrical stress, and all the capacitors are operated at 50 percent electrical stress. There is both device burn-in and unit burn-in, for which the manufacturer would like to receive credit. The unit burn-in consists of 72 hours at 70 °C. In addition, all the bipolar and MOS integrated circuits are burned in for 168 hours at 150 °C. Under these conditions, reliability predictions for the unit EXAMPLE must be calculated using Forms 5 and 6. Figures 5 and 6 illustrate completed forms for this example and are shown on the following pages.

## 6.6 Instructions for Device Types/Technologies not in Table A

*Surface Mount Technology:* RPP base failure rate predictions for surface mount devices are equal to the RPP predictions for the corresponding conventional versions.<sup>12</sup>

*New or Application Specific Device Types:* There may be cases where failure rate predictions are needed for new or application-specific device types that are not included in Table A. In such cases, the supplier may use either of the following, subject to approval from the requesting organization:

- The RPP failure rate prediction for the Table A device type that is most similar
- A prediction from another source.

The requesting organization may require the supplier to provide full supporting information, and has the option to accept or reject the proposed failure rate prediction.

## 6.7 Items Excluded From Unit Failure Rate Calculations

### 6.7.1 Default Exclusions

When unit failure rates are being predicted, wire, cable, solder connections, wire wrap connections, and printed wiring boards (but not attached devices and connector fingers) may be excluded.

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12. At this time, Bellcore has received no evidence indicating a significant difference in failure rates between conventional and surface mount devices. Separate failure rate predictions for surface mount devices may be included in future RPP issues if equipment suppliers or users contribute valid field reliability data or other evidence that indicates a significant difference.

# Device Reliability Prediction Worksheet

(GENERAL CASE - Including Limited Stress)

Date		8/1/88		Page 1 Of 1	
Unit		EXAMPLE 3		Manufacturer XYZ, Inc.	

  

Device type		IC, bip	IC, NMOS	TRANS, SI	Capaci	LED	Cumulative sum of (f)	
Part number		A65BC	A73X4	T16AB	C25BV	L25X4		
Circuit ref. symbol		U1-10	U11-15	01-5	C1-5	CR1		
Quantity	$N_i$	(a)	10	5	5	5		1
Generic failure rate †	$\lambda_{G_i}$	(b)	38	110	25	3		200
Quality factor	$\pi_{Q_i}$	(c)	1.2	1.2	1.2	1.5		1.8
Stress factor	$\pi_{S_i}$	(d)	1.0	1.0	0.8	1.0		1.0
Temperature factor	$\pi_{T_i}$	(e)	1.2	1.3	1.1	1.0		1.5
Device quantity x device failure rate (a)x(b)x(c)x(d)x(e)		(f)	456	715	110	23	540	1844
Unit burn-in								
Temperature	$T_{b,u}$		70°	70°	70°	70°	70°	
Acceleration factor*	$A_{b,u}$	(g)	3.7	3.7	3.7	3.7	3.7	
Time	$t_{b,u}$	(h)	72	72	72	72	72	
System burn-in								
Temperature	$T_{b,s}$							
Acceleration factor*	$A_{b,s}$	(i)						
Time	$t_{b,s}$	(j)						
Device burn-in								
Temperature	$T_{b,d}$		150°	150°	NA	NA	NA	
Acceleration factor*	$A_{b,d}$	(k)	48	48	NA	NA	NA	
Time	$t_{b,d}$	(m)	168	168	NA	NA	NA	
Early Life Temp. Factor*	$A_{op}$	(n)	1.3	1.3	1.3	1.3	1.3	
10000/[(d)x(e)]		(o)	8333	7692	11,363	10000	6667	Cumulative sum of (u)
(g)x(h) + (l)x(j) + (k)x(m)		(p)	8330	8330	266	266	266	
Eff. burn-in time: (p)/[(d)x(n)]		(q)	6408	6408	256	205	205	
(1) If (q) ≥ (o)	(r) = 1	(r)						
(2) If (q) ≤ (o) - 8760 Look up (q) in Table I		(s)			2.6	2.7		
(r) = (s)/[(d)x(e)] <sup>0.75</sup>		(r)			2.6	2.7		
(3) Otherwise Look up (p) in Table I		(t)	1.0	1.0			2.6	
(r) = [(t)-1]/[(d)x(e)] + 1		(r)	1.0	1.0			2.1	
(r)x(t)		(u)	456	715	286	62	1134	2653

\*Obtain From Table G, Curve 7

†Failure rates come from Table A. If Method II is applied to devices, use (g) from Form 11.

Figure 5. Example 3, Case 3 (Worked Form 5)

## Unit Reliability Prediction Worksheet

(GENERAL CASE - Including Limited Stress)

Date		8/1/88		Page		1 Of 1	
Product		APPARATUS		Rev		1	
Manufacturer		XYZ, Inc.					
Unit name		EXAMPLE 3					
Unit number		11-24					
Repair category							
Factory repairable		X					
Field repairable							
Other							
From Figure 5: Sum of (u)	(u)	2653					
From Figure 5: Sum of (f)	(f)	1844					
Environmental Factor	$\pi_E$	1.5					
$\pi_E \times (f)$	$\lambda_{SS}$	2766					
$\frac{(u)}{(f)}$	$\pi_{FY}$	1.4					
If Method II is applied to units, From Figure 12:	$\lambda_{SS}^*$	NA					
Comments:							

Figure 6. Example 3, Case 3 (Worked Form 6)

### 6.7.2 Approved Exclusions

The supplier must provide unit failure rate predictions that include all devices within the unit. However, when unit failure rate predictions are to be used as input into system reliability models, the supplier may propose that the requesting organization approve exclusion of devices whose failure will not cause an immediate loss of service, necessitate an immediate maintenance visit, or result in additional service disruption during later system maintenance activities.<sup>13</sup> This may include devices provided for monitoring, alarm, or maintenance purposes (for example, channel busy lamps or failure indicator lamps).

To propose exclusions, the supplier must use Form 7, entitled "Items Excluded From Unit Failure Rate Calculations," for each unit affected. The form should list all items that are proposed for exclusion in the unit failure rate calculation. The bottom portion of Form 7 contains a set of equations that describe the total unit failure rate and first year multiplier in terms of the contribution by "service affecting" and "non-service affecting" values. When exclusions are approved by the requesting organization, the supplier should use the "service affecting" values when completing Form 8.

### 6.7.3 Example 4

Consider the unit EXAMPLE, introduced in Example 1, Section 6.5.1. Assume that the LED is non-service affecting since it only indicates whether the unit is functioning. Form 7 must be completed. Figure 7 illustrates a completed form for this example and is shown on the following page.

## 7. METHOD II: PREDICTIONS BASED ON COMBINING LABORATORY DATA WITH PARTS COUNT DATA

### 7.1 Introduction

Method II is a method for predicting unit or device reliability using laboratory data. The purpose of the procedure is to provide a mechanism for suppliers to perform realistic and informative laboratory tests. Suppliers who submit reliability predictions based on laboratory data must obtain prior approval from the requesting organization.

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13. For example, failure of a particular device that does not immediately affect service, but will affect the system recovery time given a subsequent outage.

## Items Excluded From Unit Failure Rate Calculations

Date		8/1/88	Unit		EXAMPLE 1
Manufacturer		XYZ, Inc.			

  

Device		Reason	From Figure 2 or 5	
Type	Number		(f)	(u)*
LED, 1300 nm non-herm	L25X4	LED used for status indication only	360	1440
TOTALS				

After completing this form, calculate the following failure rate data:

Non-service Affecting		Service Affecting	
$\pi_E \times \Sigma(f) = \lambda_{SS_{na}} =$	$1.5 \times 360 = 540$	$\lambda_{SS} - \lambda_{SS_{na}} = \lambda_{SS_s} =$	$2480 - 540 = 1940$
$\frac{\Sigma(u)}{\Sigma(f)} = \pi_{FY_{na}} =$	$1440/360 = 4.0$	$\frac{\pi_{FY} \lambda_{SS} - \pi_{FY_{na}} \lambda_{SS_{na}}}{\lambda_{SS_s}} = \pi_{FY_s} =$	$4.0$
<p>Where:</p> <p><math>\pi_E</math> = environmental factor (from Form 1).</p>		<p>Where:</p> <p><math>\lambda_{SS}</math> = total unit steady-state failure rate (from Form 3, 4, 5, 10, or 12)</p> <p><math>\pi_{FY}</math> = total unit First Year Multiplier (from Form 4 or 6). When <math>\lambda_{SS}</math> comes from Form 3 or 10, <math>\pi_{FY} = 4.0</math>.</p>	

\*When the value of (f) is obtained from Form 2, (u) =  $\pi_{FY} \times f$ . Obtain the value of  $\pi_{FY}$  from Form 3, 4, or 6, whichever is applicable.

Comments:

For the above computations, note that in Example 1,  $\pi_{FY} = 4.0$ .

Figure 7. Example 4 (Worked Form 7)

Decisions to implement lab tests need to be made on a case-by-case basis and must be carefully considered. The cost of a lab test must be weighed against the impact of Method I device failure rates on unit failure rates and/or system reliability parameter estimates (relative to reliability objectives). Life cycle costs should also be considered. The Method II base failure rate is calculated as a weighted average of the measured laboratory failure rate and the Parts Count generic failure rate, with the weights determined by the laboratory data. For devices, the value for the generic failure rate is obtained from Table A; for units, the value is  $\lambda_{SS}/(\pi_E \pi_T)$ . (These terms will be defined later.) When laboratory tests are very informative, the Method II base failure rate is determined primarily from the laboratory data. When laboratory tests are less informative, the Method II base failure rate will be heavily influenced by the Parts Count generic failure rate.

Using Method II yields device or unit base failure rates to take the place of Parts Count generic failure rates. These base failure rates can then be used to compute Method II steady-state failure rates. Method II device base failure rates can also be substituted for the Table A generic failure rates in the unit level Parts Count calculations.

When unit level failure rates are to be input into system level reliability models, Method II unit steady-state failure rates should be substituted for the Parts Count failure rates wherever they appear in the system reliability model.

## 7.2 Method II Criteria

1. The supplier must provide all supporting information and Parts Count (Method I) predictions.
2. Method II may be applied only to *devices* procured or manufactured per Quality Levels II and III, unless there is no generic failure rate prediction for the device listed in Table A. For a quality level I device not listed in Table A, the requesting organization has the option to use a failure rate prediction from another source.
3. Method II may be applied only to *units* that contain devices procured or manufactured only per Quality Levels II and III, unless no generic failure rate predictions are listed in Table A for some of the devices in the unit. In such a case, the requesting organization has the option to use a failure rate prediction from another source.
4. The quality levels of devices tested in the laboratory must be representative of the quality levels of the devices for which the prediction is to be used.
5. This section provides information on how many devices or units should be tested, how long the devices or units should be tested, how the devices should be tested, etc. In the criteria below, actual time is elapsed clock time, but effective time is actual time multiplied by an appropriate temperature acceleration factor. Criteria are:

- (a) Test devices or units for an actual time of at least 500 hours. This ensures that each item is observed for a reasonable period of time -- even for highly accelerated tests.
- (b) Test devices or units for an effective time of at least 3000 hours.
- (c) Select the number of devices or units placed on test so that at least two failures can be expected. Refer to Section 7.10 for details. Also, at least 500 devices or 50 units are required.
- (d) Test devices to simulate typical field operations, e.g., humidity and stress.
- (e) Include product from a representative sample of lots to ensure representativeness of the test.

The supplier may be asked to provide additional information to demonstrate the consistency of failure rates over time.

6. Statistical predictions for devices based on Method II may be generalized to other devices that have:
- The same type/technology
  - The same packaging (e.g., hermetic)
  - The same or lower levels of complexity
  - A construction and design similar in material and technology.

A supplier who wishes to use Method II predictions for other products must explain and justify those generalizations.

The supplier may also be asked to provide additional data supporting the assertion that the products have similar reliabilities.

### 7.3 Cases for Method II Predictions

There are four general cases where laboratory data can be used for computing Method II predictions. The four cases and the worksheets (forms) provided for the calculations are:

- Case L1 - Devices are laboratory tested (devices have had no previous burn-in), Form 9.
- Case L2 - Units are laboratory tested (no previous unit/device burn-in), Form 10.
- Case L3 - Devices are laboratory tested (devices have had previous burn-in), Form 11.
- Case L4 - Units are laboratory tested (units/devices have had previous burn-in), Form 12.

The Method II formulae and equations for each case are presented in the following paragraphs. The supplier must use the equations and formulas for the case that corresponds to the collected laboratory data.

#### 7.4 Case L1 - Devices Laboratory Tested (devices have had no previous burn-in)

To calculate the Method II *base failure rate* ( $\lambda_{G_i}^*$ ):

- If  $T_1 \leq 10,000$ , then

$$\lambda_{G_i}^* = [2+n] / [(2/\lambda_{G_i}) + (4 \times 10^{-5}) N_0 (T_1)^{0.25} \pi_Q] \quad (3)$$

- If  $T_1 > 10,000$ , then

$$\lambda_{G_i}^* = [2+n] / [(2/\lambda_{G_i}) + ((3 \times 10^{-5}) + (T_1 \times 10^{-9})) N_0 \pi_Q]$$

where

- $n$  = the number of failures in the laboratory test.
- $\lambda_{G_i}$  = the device Table A generic failure rate in FITs. If no generic failure rate is listed in Table A, then a failure rate from another source may be used, subject to the approval of the requesting organization.
- $N_0$  = number of devices on test.
- $T_1$  = effective time on test in hours. The effective time on test is the product of the actual time on test ( $T_a$ ) and the laboratory test temperature acceleration factor ( $A_L$ ) from Table G, Curve 7. Form 9 is a worksheet used to calculate device base failure rates for this case.
- $\pi_Q$  = device quality factor from Table D.

When devices are laboratory tested, calculate the Method II unit steady-state failure rate from the device steady-state failure rates by replacing  $\lambda_{G_i}$  by  $\lambda_{G_i}^*$  in the appropriate Section 6 equation [Equation (1) or (2)]. These calculations are made explicit in Forms 2 and 5.

### 7.5 Case L2 - Units Laboratory Tested (no previous unit/device burn-in)

When units are tested in the laboratory, the following formula describes how to calculate the Method II *base failure rate* ( $\lambda_G^*$ ):

- If  $T_1 \leq 10,000$ , then

$$\lambda_G^* = [2+n] / [(2/\lambda_G) + (4 \times 10^{-6}) N_0 (T_1)^{0.25}] \quad (4)$$

- If  $T_1 > 10,000$ , then

$$\lambda_G^* = [2+n] / [(2/\lambda_G) + ((3 \times 10^{-5}) + (T_1 \times 10^{-9})) N_0]$$

where

$n$  = the number of failures in the laboratory test.

$\lambda_G$  = the unit generic failure rate in FITs. It equals  $\lambda_{SS}/(\pi_E \pi_T)$ , where  $\lambda_{SS}$  is the Method I unit steady-state failure rate computed in Section 6.2.2,  $\pi_T$  is the unit temperature acceleration factor due to normal operating temperature (Table G, Curve 7), and  $\pi_E$  is the environmental factor used in the computation of  $\lambda_{SS}$ . If no Method I prediction can be computed for a unit, then a failure rate prediction from another source may be used, subject to the approval of the requesting organization.

$N_0$  = number of units on test.

$T_1$  = effective time on test in hours. The effective time on test is the product of the actual time on test ( $T_a$ ) and the laboratory test temperature acceleration factor ( $A_L$ ) from Table G, Curve 7.

When units are tested in the laboratory, the Method II unit steady-state failure rate is  $\lambda_G \pi_E \pi_T$ . Form 10 is a worksheet used to calculate unit steady-state failure rates for this case.

### 7.6 Example 5

Consider the unit EXAMPLE from Example 1 (Section 6.5.1). Assume 500 units are tested at 65 °C for 1000 hours, resulting in 3 failures. Assume also that the unit will be normally operated at 40 °C. The Parts Count prediction was 2157 FITs.

Solution: For this example, the effective time on test is calculated:

$$T_1 = T_a \cdot A_L = 1000 \cdot 3 = 3000 \text{ hours,}$$

where the acceleration factor ( $A_L$ ) comes from Table G, Curve 7.  $(T_1)^{0.25}$  can be calculated by taking the square root of  $T_1$  twice:

$$(3000)^{0.25} = \sqrt{\sqrt{3000}} = \sqrt{55} = 7.4.$$

Since  $N_0 = 500$ ,

$$0.000004 N_0 (T_1)^{0.25} = 0.000004 \cdot 500 \cdot 7.4 = 0.0148$$

And since  $\lambda_{SS} = 2157$ ,  $\pi_T = 1.0$ , and  $\pi_E = 1.5$ , it follows that  $\lambda_G = 1438$ . So,  $2/\lambda_G = 2/1438 = 0.0014$ .

Therefore, the denominator of Equation (4) is 0.0162. Since  $n = 3$ , the numerator of Equation (4) is 2+3 or 5. So the laboratory method base failure rate is:

$$\lambda_G^* = 5/0.0162 = 309 \text{ FITs.}$$

The unit steady-state failure rate is  $309 \cdot 1.5 = 464 \text{ FITs.}$

### 7.7 Case L3 - Devices Laboratory Tested (devices have had previous burn-in)

When there is burn-in, calculation of the Method II estimators is more complicated. Define the total effective burn-in time for Method II for *devices* to be:

$$T_e = A_{b,d} t_{b,d}$$

where

$A_{b,d}$  = temperature acceleration factor (from Table G, Curve 7) due to device burn-in

$t_{b,d}$  = device burn-in time (hours).

The Method II base failure rate ( $\lambda_{G_i}^*$ ) is:

$$\lambda_{G_i}^* = [2+n]/[(2/\lambda_{G_i}) + (4 \times 10^{-6})N_0 W \pi_Q]$$

where  $n$ ,  $\lambda_{G_i}$ , and  $N_0$  are defined in Section 7.4, and  $W$  is calculated as follows:

- If  $T_1 + T_e \leq 10000$ , then

$$W = (T_1 + T_e)^{0.25} - T_e^{0.25}$$

- If  $T_1 + T_e > 10,000 \geq T_e$ , then

$$W = ((T_1 + T_e)/4000) + 7.5 - T_e^{0.25}$$

- If  $T_e > 10,000$ , then

$$W = T_1/4000$$

where  $T_1$  is the effective time on test.

Form 11 is a worksheet that can be used to calculate device base failure rates in this case.

When devices are laboratory tested, calculate the Method II unit steady-state failure rate from the device steady-state failure rates by simply replacing  $\lambda_{G_i}$  by  $\lambda_{G_i}^*$  in the appropriate Section 6 equation [Equation (1) or (2)]. These calculations are made explicit in Form 11.

## 7.8 Case L4 - Units Laboratory Tested (units/devices have had previous burn-in)

For units tested in the laboratory, the total effective burn-in time for Method II is

$$T_e = T_{b,d}^* + A_{b,u} t_{b,u}$$

where

$T_{b,d}^*$  = device average effective burn-in time.

$A_{b,u}$  = temperature acceleration factor (from Table G, Curve 7) corresponding to the unit burn-in temperature.

$t_{b,u}$  = unit burn-in time (hours).

The following formula describes how to calculate the Method II base failure rate ( $\lambda_G^*$ ):

$$\lambda_G^* = [2+n]/[(2/\lambda_G) + (4 \times 10^{-6})N_0 W]$$

where  $n$ ,  $\lambda_G$ , and  $N_0$  are defined in Section 7.5 and  $W$  is calculated as follows:

- If  $T_1 + T_e \leq 10000$ , then

$$W = (T_1 + T_e)^{0.25} - T_e^{0.25}$$

- If  $T_1 + T_e > 10000 \geq T_e$ , then

$$W = ((T_1 + T_e)/4000) + 7.5 - T_e^{0.25}$$

- If  $T_e > 10000$ , then

$$W = T_1/4000$$

where  $T_1$  is the effective time on test.

Form 12 is a worksheet that can be used to calculate unit base failure rates in this case.

When *units* are tested in the laboratory, the Method II unit steady-state failure rate is  $\lambda_{G\pi E\pi T}^*$ .

## 7.9 Example 6

Consider the unit EXAMPLE from Example 1 (Section 6.5). Assume that there are 1000 hours of unit burn-in at 70 °C, and that the unit will be operated at 40 °C. Under these conditions, reliability predictions are calculated as shown below.

Solution: As before,  $n = 3$ ,  $\lambda_G = 1438$ , and  $N_0 = 500$ . Only  $W$  must be calculated. To calculate  $W$ , first calculate  $T_e$ .

$$T_e = T_{b,d}^* + A_{b,u} t_{b,u} = 0 + 3.7 \cdot (1000) = 3700$$

The factor 3.7 comes from Column 7 of Table G.  $W$  is given by

$$W = (3000+3700)^{0.25} - (3700)^{0.25} = 1.25$$

Therefore,

$$\lambda_G^* = 5 / (0.0014 + 0.0025) = 1282 \text{ FITs}$$

The unit steady-state failure rate is  $1282 \cdot 1.5 = 1923 \text{ FITs}$ .

## 7.10 Calculation of the Number of Units or Devices on Test

The following formula gives the number ( $N_0$ ) of units or devices to be placed on test so that at least two failures can be expected:

$$N_0 = (0.5 \times 10^6) / [R((T_1 + T_e)^{0.25} - T_e^{0.25})]$$

where

$R$  = the Method I prediction, if one can be computed. If no Method I prediction can be computed, then a prediction from an alternate source may be used, subject to approval from the requesting organization.

$T_1$  = effective time on test in hours (see Section 7.4 for devices and Section 7.5 for units).

$T_e$  = effective burn-in time, if any, in hours (see Section 7.7 for devices and Section 7.8 for units).

## 8. GUIDELINES FOR METHOD III: STATISTICAL PREDICTIONS FROM FIELD TRACKING

### 8.1 Introduction

Suppliers who submit device or unit level steady-state reliability predictions based on field tracking data must obtain prior approval from the requesting organization and be able to justify use of the selected approach. That is, the burden of proof is on the supplier.

Field tracking data and supporting information must meet the criteria listed later in this section. The field tracking process, system, and data must be available for review by the requesting organization to ensure that these criteria have been satisfied.

Field tracking data may be used for direct computation of field failure rates at the unit or device level, depending on the supporting information provided. The unit or device level field failure rates are then used to determine the Method III unit or device level steady-state<sup>14</sup> failure rate predictions, which can then be applied in a system level reliability model for the supplier's system.

The Method III failure rate prediction is a weighted average of the observed field failure rate and the Parts Count prediction, with the weights determined by the field data. When there are a large number of total operating hours for a device or unit during a field tracking study, the Method III failure rate prediction is heavily influenced by the field data. When there are a small number of total operating hours, the Method III failure rate prediction is more heavily influenced by the parts count prediction.

### 8.2 Applicability

The Method III procedure and computations are intended for application to field data collected from a population of devices or units that are all in the steady-state phase of operation, but the procedure may be applied to field data collected from a population of devices or units that does not meet this condition. However, no infant mortality adjustment to the Method III prediction is permitted.

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14. Method III does not include procedures for predicting failure rates or other measures of reliability during the infant mortality phase of operation.

## 8.3 Definitions and Symbols

### 8.3.1 Definitions

**Subject system**— if unit level failure rate predictions are to be used for analysis of a particular system, *subject system* refers to that system.

**Subject unit** refers to a unit-type that belongs to the subject system.

**Tracked systems** refers to the particular sample of in-service systems from which field tracking data is collected. The tracked systems may be of a different type than the subject system [see Section 8.4, Methods III(b) and III(c)].

**Tracked unit** refers to a unit in the tracked systems for which reliability data is being collected. A tracked unit may be of a different type than the corresponding subject unit for which the reliability is being predicted [see Section 8.4, Method III(c)].

### 8.3.2 Symbols

- $t$  - Total Operating Hours of the device or unit in the tracked systems
- $f$  - number of failures observed in the tracked systems in time  $t$  (field failure count)
- $N_i$  - quantity of  $i^{th}$  device
- $\lambda_{SS1}$  - For a subject unit: the Method I steady-state failure rate prediction  $\lambda_{SS}$ .  
For a subject device: the Method I steady-state failure rate prediction  $\lambda_{SS_i}$ , multiplied by the environmental factor,  $\pi_E$ , for the subject system.

That is:

$$\lambda_{SS1} = \lambda_{SS}, \text{ for a subject unit, and}$$

$$\lambda_{SS1} = \pi_E \lambda_{SS_i}, \text{ for a subject device.}$$

$\lambda_{SS}$  and  $\lambda_{SS_i}$  may be either the Method I Case 1 (black box) or Case 3 (limited stress) predictions, as specified in Section 8.6.

- $\lambda_{SS2}$  - For a tracked unit (when different from the subject unit): the Method I Case 3 steady-state failure rate prediction. That is:

$$\lambda_{SS2} = \lambda_{SS},$$

where  $\lambda_{SS}$  is the Method I, Case 3 steady-state failure rate prediction for the tracked unit.

- $\Theta_{SSi}$  - the Method III failure rate prediction for the  $i^{th}$  device
- $\Theta_{SS}$  - the Method III unit failure rate prediction
- $\Theta_{SS3}$  - general symbol used for a Method III unit or device level failure rate prediction.
- $\pi_{T1}, \pi_{T2}$  - the temperature factors from RPP Table G for the device or unit operating under normal temperatures in the subject (1) and tracked (2) system. For devices, use the temperature stress curve indicated in Table A. For units, use temperature stress curve 7.

## 8.4 Method III Criteria and Procedure

### 8.4.1 Source Data

When unit level reliability predictions are to be used as input to a system reliability model for evaluation of a supplier's system, three general categories of field data may be used to compute Method III predictions. Methods III(a), III(b), and III(c) are specified based on the source category of the field data.

#### Method III(a)

Statistical predictions of the failure rates of device types, unit types, or subsystems based on their in-service performance as part of the subject system.

#### Method III(b)

Statistical predictions of the failure rates of device types, unit types, or subsystems of the subject system based on their in-service performance as part of another system. Proper adjustments of those estimates, which take into account all differences between the operating conditions/environment of the equipment items in the two systems, are required in all cases.

### Method III(c)

Statistical predictions of the failure rates of unit types or subsystems (excluding device types) of the subject system based on the in-service performance of similar equipment items from the same manufacturer that have a construction and design similar in material and technology and that are used in similar applications and environments. This does not imply that reliability parameters estimated for similar items can be directly applied to the unit types or subsystems of the subject system. Proper adjustments of those estimates, which take into account all design and operating condition differences between the tracked equipment items and those in the subject system for which the failure rates are being estimated, are required in all cases. A supplier who uses Method III(c) must explain and justify those adjustments.

#### 8.4.2 Study Length and Total Operating Hours

This section specifies the length of the field tracking study and the total operating hours required when using Method III. The Criteria are:

1. The field tracking study must cover an elapsed clock time of at least 3000 hours.
2. The total operating hours  $t$  must satisfy the following:

*For Methods IIIa and IIIb:*

$$t \geq \frac{2 \cdot 10^9}{\lambda_{SS1}},$$

*For Method IIIc:*

$$t \geq \frac{2 \cdot 10^9}{\lambda_{SS2}}.$$

#### 8.4.3 Subject Unit or Device Selection

Use of Method III failure rate predictions in system reliability models is permitted as follows:

- When Method III predictions are submitted for all unit or device types that make up the subject system
- When Method III predictions are submitted for a set of subject unit or device types that have been selected by the requesting organization
- When Method III predictions are submitted for a set of subject unit or device types that meet some criteria designated by the requesting organization—for example, unit types whose failure rates account for more than some designated percentage of the total individual line downtime.

#### 8.4.4 Quality and Environmental Level

Method III failure rate predictions are permitted for devices of any quality level and for units containing devices of any quality level, subject to the following:

- The quality levels (see Table C) of devices used in the subject system must be equal to or better than the quality levels of the devices in the tracked systems.
- For a Quality Level I device type, the requesting organization has the option to use the Method III prediction, the Method I prediction or, if no generic failure rate is included in Table A, a failure rate prediction from another source.
- For a unit type that contains Quality Level I devices, the requesting organization has the option to use the Method III prediction, the Method I prediction or, if the unit contains devices for which no generic failure rate is included in Table A, a failure rate prediction from another source.

Method III failure rate predictions are permitted for devices or units deployed in a ground benign, ground fixed, or ground mobile environment (see Table H), subject to the following:

- The environmental level of the subject system must be the same or less severe than the environmental level of the tracked systems.

#### 8.5 Field Data and Information

The supplier must *provide* the following field data and supporting information:

- The definition of "failure" for each unit type being tracked, and for each device type for which Method III predictions are to be computed.
- A general description of how a "no trouble found" (NTF) is determined for a returned unit, and a complete description of any failure mode that is not counted as a failure in the field tracking study (e.g., handling damage).
- Unit types and quantities (in-service and spare) for each tracked system. If field data is to be used for device-level reliability predictions, then the device types and quantities must also be provided for each unit type tracked during the field tracking study.
- The total operating hours during the field tracking study for each unit type being tracked, and for each device type for which Method III predictions are to be computed. The general formula used to compute the total operating hours must also be provided.

- The total number of failures for each unit type tracked during the study. If the data is to be used for device-level reliability predictions, then the total number of failures for each device type must also be included.

The supplier must maintain the following historical and accounting information and provide any part of it upon request:

1. For any unit (in-service or spare) deployed in the tracked systems during the study period
  - A unique identification number, serial number, or bar code— the number or bar code must be on the unit and clearly visible
  - Date the unit was available for deployment
  - Shipment date
  - Destination (site or system)
  - Date returned to repair facility due to possible failure
  - Results of test (failure or "no trouble found")
  - The identity of devices that had failed and were replaced in the failed unit (for device level reliability predictions only)
  - Date repaired unit was available for re-deployment.
2. The results of weekly (or more frequent) repair/shipping activity audits that confirm all units are accounted for and all maintenance actions are properly recorded. The audits must cover all processing, testing, repair, and data entry activity for units returned or shipped out during the auditing period (for all company and external repair activities). Repair activities conducted at field locations (if any) must also be covered.

## 8.6 Method III Procedure

*Step 1:* Determine the number of field failures,  $f$ , and the total operating hours,  $t$ , for the unit or device in the tracked systems.

*Step 2:* If using Methods IIIb or IIIc, determine the operating temperature factors  $\pi_{T1}$  and  $\pi_{T2}$  as defined in Section 8.3.

*Step 3:* If Table A includes the generic failure rates necessary to compute a Method I prediction for the subject device or unit, then compute the value of  $\lambda_{SS1}$ , as defined in Section 8.3 and in accordance with the following:

For Methods IIIa and IIIb: compute  $\lambda_{SS1}$  using either the Method I, Case 1 or Case 3 failure rate prediction, unless the choice is specified by the requesting organization.

For Method IIIc: compute  $\lambda_{SS1}$  using the Method I, Case 3 prediction.

*Step 4:* When the tracked unit is different than the subject unit (i.e., when using Method IIIc) and Table A includes the generic failure rates necessary to compute a Method I prediction for the tracked unit, then compute  $\lambda_{SS2}$ , as defined in Section 8.3.

*Step 5:* Compute the adjustment value,  $V$ , as follows:

$V =$	1.0	For Method IIIa
	$\frac{\pi_{T2}}{\pi_{T1}}$	For Method IIIb
	$\frac{\lambda_{SS2}}{\lambda_{SS1}}$	For Method IIIc

Method IIIc may not be used in cases where Table A does not include the necessary generic failure rates to compute both  $\lambda_{SS1}$  and  $\lambda_{SS2}$  as defined in Section 8.3 and in accordance with Step 3 above.

*Step 6:* Calculate the Method III failure rate prediction,  $\Theta_{SS3}$ , as follows:

$$\Theta_{SS3} = \frac{2 + f}{\frac{2}{\lambda_{SS1}} + (V \cdot t \cdot 10^{-9})}$$

The adjustment value,  $V$ , is computed in Step 5 above.

*If  $\lambda_{SS1}$  is not available:* the Method IIIa and Method IIIb failure rate prediction,  $\Theta_{SS3}$ , is computed as follows:

$$\Theta_{SS3} = \frac{10^9 \cdot U}{t \cdot V}$$

where  $V$  is computed in Step 5 above, and  $U$  is the upper 90 percent confidence limit on the failure rate, given that  $f$  field failures were observed. The values of  $U$  are provided in Table K for  $f$  ranging from 0 to 160.

## 8.7 Examples

### 8.7.1 Example 1; Unit Level, Method III(a)

A supplier has field tracking data on a remote switching terminal that meets all Method III criteria. The total operating hours for circuit pack #xyz during the study period is  $10^8$  hours, with field failure count  $f = 70$  and an operating temperature of  $50^\circ\text{C}$ . For circuit pack #xyz (ground fixed environment)  $\lambda_{SS1} = 600$  FITs, and is computed using the Method I, Case 1 prediction.

From Step 5,  $V = 1.0$ , and from Step 6:

$$\Theta_{SS} = \frac{2 + 70}{\frac{2}{600} + (1.0 \cdot 10^8 \cdot 10^{-9})} = 697 \text{ FITs.}$$

### 8.7.2 Example 2; Unit Level, Method III(b)

A supplier has unit level field tracking data for circuit pack #xyz from the operation of System 2 remote switching terminals and wants to use that data to predict the failure rate of circuit pack #xyz operating in System 1 remote switching terminals. Both systems operate in a ground fixed environment. The field failure count for the pack in System 2 is  $f = 70$  with total operating time  $t = 10^8$  hours. The operating temperature of the pack is  $55^\circ\text{C}$  in System 1 and  $50^\circ\text{C}$  in System 2.  $\lambda_{SS1} = 600$  FITs, and is computed using the Method I, Case 1 prediction.

From Table G, Curve 7,  $\pi_{T1} = 2.0$  and from Step 5,

$$V = \frac{\pi_{T2}}{\pi_{T1}} = \frac{1.6}{2.0} = 0.8.$$

Then from Step 6:

$$\Theta_{SS} = \frac{2 + 70}{\frac{2}{600} + (0.8 \cdot 10^8 \cdot 10^{-9})} = 864 \text{ FITs.}$$

## 9. SERIAL SYSTEM RELIABILITY (SERVICE AFFECTING RELIABILITY DATA)

### 9.1 Steady State Failure Rate

If the specified reliability parameters, failure criteria, equipment configuration, and operating conditions indicate that a serial reliability model is appropriate, the total system failure rate,  $\lambda_{SYS}$ , will be the sum of all the unit steady-state failure rates,  $\lambda_{SS}$ . That is,

$$\lambda_{SYS} = \sum_{j=1}^M \lambda_{SS(j)}$$

where  $\lambda_{SS(j)}$  is the unit steady-state failure rate for unit  $j$  and  $M$  is the number of units. The discussion in early subsections of Section 6 omitted the subscript  $j$  for simplicity since there was only one unit. Note that unit steady-state failure rates are assumed to reflect only service affecting failures. The unit failure rates come from Form 3, 4, or 6, depending on whether Case 1, 2, or 3, respectively, was used (see Sections 6.2 and 6.4). It is assumed that these unit failure rates have been modified to remove non-service affecting failures (see Form 7 and Section 6.6). However, before doing so, the service impact of repairing faults in non-service affecting components should be considered.

### 9.2 First Year Multiplier

The system first year multiplier  $\pi_{FYSYS}$  for a serial system is given by:

$$\pi_{FYSYS} = \frac{\sum_{j=1}^M \lambda_{SS(j)} \pi_{FY(j)}}{\lambda_{SYS}}$$

where  $\pi_{FY(j)}$  is the unit first year multiplier for the  $j^{\text{th}}$  unit.

### 9.3 Applicability

Many communications systems do not conform to a serial reliability model. If the requesting organization concludes that the serial model is inappropriate, a suitable reliability model must be developed. Complex systems will require the application of techniques described in various reliability engineering references (for example,

*Probabilistic Reliability: An Engineering Approach*,<sup>2</sup> "Practical Markov Modeling for Reliability Analysis,"<sup>3</sup> and *Methods and Procedures for System Reliability*<sup>4</sup>).

Specification of reliability modeling techniques for complex systems is beyond the scope of this procedure. The supplier must submit drawings, diagrams, or specifications necessary to substantiate the reliability model.

#### 9.4 Assumptions and Supporting Information

In developing repair rates or expected times to restore service, it may be assumed that all necessary test equipment and replacement units are present and operational. The supplier must state assumptions concerning the numbers of maintenance craftspersons, particularly for the case of multiple failures. Supporting information for the estimated repair rates or expected times to restore service must also be provided. Evidence should include descriptions of alarms or other failure detection and reporting capabilities, as well as travel time assumptions, and manual or automatic diagnostic aids.

#### 9.5 Reporting

Enter the reliability determinations on Form 8, the "System Reliability Report" (Figure 15).

The supplier should present any additional reliability information or factors that enhance or detract from the equipment reliability by completing Form 13, the "Additional Reliability Data Report" (Figure 20). Quantitative effects on equipment reliability must be described.

The supplier must provide nonproprietary design information, such as functional block diagrams, parts lists, procurement specifications, and test requirements, as requested in preceding paragraphs or required by the requesting organization. Each submitted document should be included on Form 14, the "List of Supporting Documents" (Figure 21).

### 10. FORM/WORKSHEET EXHIBITS AND PREPARATION INSTRUCTIONS

The following pages include form/worksheet exhibits and associated preparation instructions for the reliability prediction procedure. These worksheets and instructions may be copied and used as needed.

## 11. REFERENCES

- [1] *Reliability Prediction of Electronic Equipment*, MIL-HDBK-217, RADC, Griffis Air Force Base, New York, October 27, 1986.
- [2] Shooman, M. L., *Probabilistic Reliability: An Engineering Approach* (McGraw-Hill, 1968).
- [3] Kitchin, J. F., "Practical Markov Modeling for Reliability Analysis," 1988 *Proceedings of the Annual Reliability and Maintainability Symposium*, pp. 290-296.
- [4] *Methods and Procedures for System Reliability Analysis*, SR-TSY-001171, Bellcore, Issue 1, January 1989.
- [5] *Component Reliability Assurance Requirements for Telecommunications Equipment*, TR-TSY-000357, Bellcore, Issue 1, December 1987.

## NOTE

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REQUEST FOR RELIABILITY PREDICTION

Product \_\_\_\_\_

Request Date \_\_\_\_\_

Manufacturer \_\_\_\_\_

Estimate Due \_\_\_\_\_

LIFE CYCLE COST DATA REQUESTED:

- ☐ Steady-state failure rate for each unit ( $\lambda_{ss}$ )
- ☐ Time averaged first year failure rate multiplier ( $\pi_{FY}$ )

SERVICE AFFECTING SYSTEM RELIABILITY PARAMETERS REQUESTED:

DEFINITION OF A SYSTEM FAILURE:

OPTIONS PER PARTS COUNT METHOD:

- ☐ Supplier May Use Any Case
- ☐ Limited Stress only - Supplier Must Use Case 3
- ☐ Sampled Limited Stress - Supplier Must Use Case 3 on a Sample of Units

RELIABILITY PREDICTION METHOD:

- ☐ Method I: Parts Count
- ☐ Method II: Combination of Laboratory Data & Parts Count
- ☐ Method III: Field Tracking Data - Also include Parts Count Method
- ☐ Other \_\_\_\_\_

OPERATING CONDITIONS:

STEADY-STATE RELIABILITY OBJECTIVES:

ENVIRONMENT(S):  $\pi_E =$

ADDITIONAL INFORMATION REQUESTED FROM SUPPLIER:

SEND RESPONSE TO: \_\_\_\_\_

Figure 8. Request for Reliability Prediction (Form 1)

Instructions for Form 2:

Worksheet for Device Reliability Prediction

Case 1 or 2: Black Box Estimates (50% Stress, Temperature = 40 ° C, No Device Burn-In)

- [1] Provide the items of information requested on the top portion of the form.
- [2] Fill in one row of the form for each device used in the unit. If more than one device will have the same value in each of the columns, the devices may be combined on one row.
- [3] Enter the device type. The description should be sufficient to verify that the correct failure rate was selected.
- [4] Enter the device part number. If multiple devices are listed in a row, the base part number is sufficient.
- [5] Enter the circuit reference symbol(s).
- [6] Record the quantity ( $N_i$ ) of devices covered in the row.
- [7] Record the base failure rate ( $\lambda_{G_i}$ ). For Method I, this value may be obtained from Table A. If a device is not listed in Table A, select a failure rate for a device that is most like the unlisted device. If no reasonable match can be made, use available field data, test data, or the device manufacturer's reliability estimate. Document and submit the rationale used in determining the failure rate. When using failure rates calculated according to Method II, enter  $\lambda_{G_i}$  from Form 9 or 11.
- [8] Record the quality factor ( $\pi_{Q_i}$ ). Use the guidelines in Table C to evaluate the device procurement and test requirements and to determine the appropriate quality level for the device. Submit representative examples of procurement specifications and quality/test requirements to justify use of quality levels other than Level I. Select a Quality Factor ( $\pi_{Q_i}$ ) in Table D that corresponds to the quality level that was determined for each device.
- [9] Determine the total device failure rate by performing the calculation indicated in the last column.
- [10] When all devices in a unit have been accounted for, sum the last column.
- [11] Use the equation on the bottom of Form 2 to calculate the unit  $\lambda_{SS}$ . Be sure to include the  $\pi_E$  term obtained from Form 1.



Instructions for Form 3

Worksheet for Unit Reliability Prediction

Case 1: Black Box Estimates (50 % Stress, Temperature = 40 ° C, Unit/System Burn-In  $\leq$  1 Hour, No Device Burn-In)

- [1] Provide the items of information requested on the top portion of the form.
- [2] Fill in one row of the form for each unit-type comprising the product.
- [3] Indicate the repair category by placing an (X) in the appropriate column.
- [4] Enter the unit steady-state failure rate ( $\lambda_{ss}$ ) obtained from the bottom of Form 2.
- [5] If units are lab tested and Method II is being applied, enter  $\lambda_{ss}^*$  from Form 10.

## Unit Reliability Prediction Worksheet

Case 1 - Black Box Estimates (50% Stress, Temperature = 40 °C,  
Unit/System Burn-in ≤ 1 Hour, No Device Burn-in)

[illegible]

Figure 10. Unit Reliability Prediction, Case 1 (Form 3)

Instructions for Form 4

Worksheet for Unit Reliability Prediction

Case 2: Black Box Estimates (50% Stress, Temperature = 40 °C, No Device Burn-In, Unit/System Burn-In  $\geq 1$  Hour)

- [1] Provide the items of information requested on the top portion of the form.
- [2] Fill in one column of the form for each unit comprising the product.
- [3] Indicate the repair category by placing an (X) in the appropriate row.
- [4] If more than one hour of equivalent operating time at 40 °C is accumulated on the unit prior to final acceptance of the product, provide the operating data as follows:

$T_{b,u}$  = Unit burn-in temperature ( °C )

$A_{b,u}$  = Arrhenius acceleration factor (Table G, Curve 7) corresponding to the unit burn-in temperature

$t_{b,u}$  = Unit burn-in time (hours)

$T_{b,s}$  = System burn-in temperature ( °C )

$A_{b,s}$  = Arrhenius acceleration factor (Table G, Curve 7) corresponding to the system burn-in temperature

$t_{b,s}$  = System burn-in time (hours). If more than one burn-in temperature is involved in unit or system burn-in, record the additional  $T_b$ ,  $A_b$ , and  $t_b$  values in the appropriate row. The same column may be used to record multiple sets of  $T_b$ ,  $A_b$ , and  $t_b$  data.

- [5] Determine the effective burn-in time ( $t_e$ ) accumulated as a result of unit and system burn-in. Be sure to include all  $T_b$ ,  $A_b$ , and  $t_b$  values.
- [6] Take the unit first year failure rate multiplier ( $\pi_{FY}$ ) from Table I.
- [7] Record the unit steady state failure rate  $\lambda_{SS}$  (obtained from the bottom of Form 2, or, when using results from Method II, use  $\lambda_{SS}$  from the bottom of Form 12).
- [8] When Method II is applied to units, enter  $\lambda_{ss}^*$  from the bottom of Form 12.

## Unit Reliability Prediction

### Worksheet

Case 2 - Black Box Estimates (50% Stress, Temperature = 40°C,  
No Device Burn-in, Unit/System Burn-in > 1 Hour)

Date		Page ____ Of ____				
Product		Rev		Manufacturer		
Unit name						
Unit Number						
Repair category						
Factory repairable						
Field repairable						
Other						
Unit burn-in						
Temperature $T_{b,u}$						
Acceleration factor $\ddagger A_{b,u}$						
Time $t_{b,u}$						
System burn-in						
Temperature $T_{b,s}$						
Acceleration factor $\ddagger A_{b,s}$						
Time $t_{b,s}$						
Effective burn-in time $t_e$						
$t_e = A_{b,u}t_{b,u} + A_{b,s}t_{b,s}$ (a)						
First year Multiplier (Table I)	$\pi_{FY}$					
$\lambda_{SS}$ (from Figure 2)	$\lambda_{SS}$					
If Method II is applied to units, from Figure 12	$\lambda'_{SS}$					
Comments:						

$\ddagger$  Obtain From Table G, Curve 7

Instructions for Form 5

Worksheet for Device Reliability Prediction

Case 3: General Case

- [1] Provide the items of information requested at the top of the form.
- [2] Fill in one column of the form for each device in the unit. If more than one device will have the same value in *each* of the rows, they may be combined.
- [3] Enter the device type. The description should be sufficient to verify that the correct failure rate was selected.
- [4] Enter the device part number. If multiple devices are listed in a column, the base part number is sufficient.
- [5] Enter the circuit reference symbol(s).
- [6] Record the quantity ( $N_i$ ) of devices covered in the column.
- [7] Record the base failure rate ( $\lambda_{G_i}$ ). For Method I, this value is obtained from Table A. If a device is not listed in Table A, select the failure rate for the device most like the unlisted device. If no reasonable match can be made, use field data, test data, or the device manufacturer's reliability estimate. Document and submit the rationale used to determine the failure rate. When using failure rates calculated according to Method II, enter  $\lambda_{G_i}^*$  from Form 9 or 11.
- [8] Record the quality factor ( $\pi_{Q_i}$ ). Use the guidelines in Table C to evaluate the device procurement and test requirements and to determine the appropriate quality level for the device. Submit representative examples of procurement specifications and quality/test requirements to justify use of quality levels other than Level I. Select a quality factor ( $\pi_{Q_i}$ ) in Table D that corresponds to the quality level that was determined for each device.
- [9] Record the stress factor ( $\pi_{S_i}$ ). Use Table A to find the applicable stress curve for the device. If no curve number is listed,  $\pi_S = 1.0$ . If a curve number is listed, evaluate the application of the device and determine the average ratio of actual to rated stress using the guidelines of Table E. Use Table F to find  $\pi_S$  based on the appropriate stress ratio and stress curve. Round off the percent stress to the nearest 10 percent prior to entering from Table F. However, percent stress may not be less than 10 percent.
- [10] Use Table A to find the applicable temperature curve for the device. Use Table G to determine the device steady-state temperature factor ( $\pi_T$ ).
- [11] Determine the product of the device quantity and the device steady-state failure rate by  $(f) = (a) \times (b) \times (c) \times (d) \times (e)$ .

- [12] Record the following burn-in data:

$T_{b,d}$  = device burn-in temperature (°C)  
 $A_{b,d}$  = Arrhenius acceleration factor (Table G, Curve 7) corresponding to the device burn-in temperature.  
 $t_{b,d}$  = device burn-in time (hours)  
 $T_{b,u}$  = unit burn-in temperature (°C)  
 $A_{b,u}$  = Arrhenius acceleration factor (Table G, Curve 7) corresponding to the unit burn-in temperature  
 $t_{b,u}$  = unit burn-in time (hours)  
 $T_{b,s}$  = system burn-in temperature (°C)  
 $A_{b,s}$  = Arrhenius acceleration factor (Table G, Curve 7) corresponding to the system burn-in temperature  
 $t_{b,s}$  = system burn-in time (hours). If more than one burn-in temperature is involved in unit or system burn-in, record the additional  $T_b$ ,  $A_b$ , and  $t_b$  values in the appropriate row. The same column may be used to record multiple sets of  $T_b$ ,  $A_b$ , and  $t_b$  data.

- [13] Calculate device first year multiplier by completing operations shown in remaining rows. To calculate (n), use the operating temperature and look up the answer in Table G, Curve 7.
- [14] Sum rows (f) and (u). Transcribe totals onto Form 6.

## Device Reliability Prediction Worksheet

(GENERAL CASE - Including Limited Stress)

Date		Page ____ Of ____	
Unit		Manufacturer	

  

Device type						
Part number						
Circuit ref. symbol						
Quantity	$N_I$	(a)				Cumulative sum of (f)
Generic failure rate †	$\lambda_{G_I}$	(b)				
Quality factor	$\pi_{Q_I}$	(c)				
Stress factor	$\pi_{S_I}$	(d)				
Temperature factor	$\pi_{T_I}$	(e)				
Device quantity x device failure rate (a)x(b)x(c)x(d)x(e)		(f)				
Unit burn-in						
Temperature	$T_{b,u}$					
Acceleration factor*	$A_{b,u}$	(g)				
Time	$t_{b,u}$	(h)				
System burn-in						
Temperature	$T_{b,s}$					
Acceleration factor*	$A_{b,s}$	(i)				
Time	$t_{b,s}$	(j)				
Device burn-in						
Temperature	$T_{b,d}$					
Acceleration factor*	$A_{b,d}$	(k)				
Time	$t_{b,d}$	(m)				
Early Life Temp. Factor*	$A_{op}$	(n)				
10000/[(d)x(e)]		(o)				Cumulative sum of (u)
(g)x(h) ÷ (i)x(j) ÷ (k)x(m)		(p)				
Eff. burn-in time: (p)/[(d)x(n)]		(q)				
(1) If (q) ≥ (o)	(r) = 1	(r)				
(2) If (q) ≤ (o) - 8760 Look up (q) in Table I		(s)				
(r) = (s)/[(d)x(e)] <sup>0.75</sup>		(r)				
(3) Otherwise Look up (p) in Table I		(t)				
(r) = [(t)-1]/[(d)x(e)] + 1		(r)				
(r)x(f)		(u)				

\*Obtain From Table G, Curve 7

†Failure rates come from Table A. If Method II is applied to devices, use (p) from Form 11.

Instructions for Form 6

Worksheet for Unit Reliability Prediction

Case 3: General Case

- [1] Provide the items of information requested on the top portion of the form.
- [2] Fill in one column of the form for each unit comprising the product.
- [3] Indicate the repair category by placing an (X) in the appropriate row.
- [4] Complete Form 5 for the devices in each unit.
- [5] After completing Form 5, sum rows (f) and (u) and transcribe the total onto Form 6.
- [6] Record the environmental factor (from Form 1)
- [7] Calculate the unit steady state failure rate ( $\lambda_{ss}$ ) by multiplying  $\pi_E$  and (f).
- [8] Calculate and record the first year multiplier ( $\pi_{FY}$ ).
- [9] If Method II is applied to this unit, record the Method II steady state failure rate taken from the bottom of Form 12.

# Unit Reliability Prediction

## Worksheet

(GENERAL CASE - Including Limited Stress)

Date		Page ____ Of ____					
Product		Rev		Manufacturer			
Unit name							
Unit number							
Repair category							
Factory repairable							
Field repairable							
Other							
From Figure 5: Sum of (u)	(u)						
From Figure 5: Sum of (f)	(f)						
Environmental Factor	$\pi_E$						
$\pi_E \times (f)$	$\lambda_{SS}$						
$\frac{(u)}{(f)}$	$\pi_{FY}$						
If Method II is applied to units, From Figure 12:	$\lambda^*_{SS}$						
Comments:							

Figure 13. Unit Reliability Prediction, General Case (Form 6)

## Items Excluded From Unit Failure Rate Calculations

		Date	Unit	
		Manufacturer		

  

Device		Reason	From Figure 2 or 5	
Type	Number		(f)	(u)*
<b>TOTALS</b>				

After completing this form, calculate the following failure rate data:

<p style="text-align: center;">Non-service Affecting</p> $\pi_E \times \Sigma(f) = \lambda_{SS_{na}} =$ <div style="border: 1px solid black; height: 20px; width: 100%;"></div> $\frac{\Sigma(u)}{\Sigma(f)} = \pi_{FY_{na}} =$ <div style="border: 1px solid black; height: 20px; width: 100%;"></div> <p>Where:</p> <p><math>\pi_E</math> = environmental factor (from Form 1).</p>	<p style="text-align: center;">Service Affecting</p> $\lambda_{SS} - \lambda_{SS_{na}} = \lambda_{SS_s} =$ <div style="border: 1px solid black; height: 20px; width: 100%;"></div> $\frac{\pi_{FY} \lambda_{SS} - \pi_{FY_{na}} \lambda_{SS_{na}}}{\lambda_{SS_s}} = \pi_{FY_s} =$ <div style="border: 1px solid black; height: 20px; width: 100%;"></div> <p>Where:</p> <p><math>\lambda_{SS}</math> = total unit steady-state failure rate (from Form 3, 4, 8, 10, or 12)</p> <p><math>\pi_{FY}</math> = total unit First Year Multiplier (from Form 4 or 6). When <math>\lambda_{SS}</math> comes from Form 3 or 10, <math>\pi_{FY} = 4.0</math>.</p>
---	--

\*When the value of (f) is obtained from Form 2, (u) =  $\pi_{FY} \times (f)$ . Obtain the value of  $\pi_{FY}$  from Form 3, 4, or 6, whichever is applicable.

Comments:

Figure 14. Items Excluded from Unit Failure Rate Calculations (Form 7)

SYSTEM RELIABILITY REPORT  
(Service Affecting Reliability Data)

System \_\_\_\_\_ Date \_\_\_\_\_

Manufacturer \_\_\_\_\_

A. Does the serial reliability model give usable results?

YES \_\_\_\_\_ (Complete A only)

NO \_\_\_\_\_ (Complete B, C, and D)

If the answer is "YES", the estimated steady-state system reliability is:

\_\_\_\_\_

B. The serial model for system reliability is inappropriate because: (Give specific reasons. List unit failure rates to be excluded or modified.)

C. The following reliability model is needed to give usable results. (Add additional pages if required.)

D. If a reliability model is included in Step (C), use it to combine the unit failure rates and repair rates or mean time to repair to obtain the appropriate reliability measure(s) of system reliability. Please show details of all calculations.

The estimated steady-state system reliability

measures are: \_\_\_\_\_

Figure 15. System Reliability Report (Form 8)

Instructions for Form 9:

Worksheet for Device Reliability Prediction, Laboratory Data

Case L1: Devices Laboratory Tested, No Burn-In

- [1] Provide the information requested on the top portion of the form.
- [2] Fill in one column of the form for each device used in the unit.
- [3] Enter the device type. The description should be sufficient to verify that the correct base failure rate was selected.
- [4] Enter the device part number.
- [5] Enter the circuit reference symbol(s).
- [6] Record the actual time spent on test ( $T_a$ ) in hours.
- [7] Record the laboratory test temperature.
- [8] Determine the laboratory test temperature acceleration factor ( $A_L$ ) from Table G.
- [9] Calculate the effective time on test ( $T_1$ ) by  $(c)=(a)\times(b)$ .
- [10] Enter the total number of laboratory failures,  $n$ .
- [11] Record the device generic failure rate ( $\lambda_{G_i}$ ). This value may be obtained from Table A. If a device is not listed in Table A, select a failure rate for a device that is most like the unlisted device. If no reasonable match can be made, use available field data, test data, or the device manufacturer's reliability estimate. Document and submit the rationale used in determining the failure rate.
- [12] Record the number of devices on test ( $N_o$ ).
- [13] Record the device quality factor  $\pi_Q$ . Obtain from Table D.
- [14] Calculate the device base failure rate ( $\lambda_{G_i}^*$ ) by performing the operations shown in the remaining rows.
- [15] To calculate the unit steady-state failure rate from these failure rates, transcribe the device base failure rate ( $\lambda_{G_i}^*$ ) onto Form 2 or 5.

## Device Reliability Prediction Laboratory Data Worksheet

Case L3-Devices Laboratory Tested (No Previous Burn-in)

Date		Page ____ Of ____	
Unit		Manufacturer	

  

Device name							
Part number							
Circuit ref. symbol							
Time on test	$T_a$	(a)					
Laboratory test							
Temperature							
Acceleration factor ‡	$A_L$	(b)					
Effective time on test (a)x(b)	$T_f$	(c)					
Number of lab failures	n	(d)					
Failure rate**	$\lambda_{Gi}$	(e)					
Number of devices on test	$N_0$	(f)					
Quality Factor	$\pi_Q$	(g)					
(1) If (c) ≤ 10,000 (h) = $4 \times 10^{-4} \times (c)^{0.25}$ (2) If (c) > 10,000 (h) = $3 \times 10^{-4} + (c) \times 10^{-6}$		(h)					
[2/(e)] + (f)x(g)x(h)		(i)					
Base failure rate [2 + (d)]/(i)	$\lambda_G$	(j)					
Comments:							

‡ Obtain From Table G, Curve 7  
\*\* Obtain From Table A

Figure 16. Device Reliability Prediction, Case L-1 (Form 9)

Instructions for Form 10:

Worksheet for Unit Reliability Prediction, Laboratory Data

Case L2: Units Laboratory Tested, No Burn-In

- [1] Provide the items of information requested on the top portion of the form.
- [2] Fill in one column of the form for each unit comprising the product.
- [3] Indicate the repair category by placing an (X) in the appropriate row.
- [4] Record the actual time spent on test ( $T_a$ ) in hours.
- [5] Record the laboratory test temperature.
- [6] Determine the laboratory test temperature acceleration factor from Table G.
- [7] Record the unit operating temperature.
- [8] Determine the operating temperature acceleration factor from Table G.
- [9] Calculate the effective time on test ( $T_1$ ) by  $(e) = (a) \times (b)$ .
- [10] Record the number of laboratory failures,  $n$ .
- [11] Transcribe the unit steady-state failure rate ( $\lambda_{SS}$ ) from Form 3.
- [12] Enter the unit environmental factor  $\pi_E$  from Form 1.
- [13] Determine the failure rate ( $\lambda_G$ ) by  $(i) = (g) / \{(h) \times (c)\}$ .
- [14] Record the number of units on test ( $N_o$ ).
- [15] Determine the unit base failure rate ( $\lambda_G^*$ ) and Method II steady-state failure rate ( $\lambda_{SS}^*$ ) by performing the operations shown in the remaining rows.

## Unit Reliability Prediction Laboratory Data Worksheet

Case L2-Units Laboratory Tested, No Previous Unit/Device Burn-in

Date		Page ____ Of ____	
Product		Rev	Manufacturer

  

Unit name							
Unit number							
Repair category							
Factory repairable							
Field repairable							
Other							
Time on test $T_a$	(a)						
Laboratory test							
Temperature							
Acceleration factor ‡	(b)						
Operation							
Temperature							
Acceleration factor ‡	(c)						
Effective time on test $T_1$ (a)x(b)	(e)						
Number of lab failures $n$	(f)						
Steady-state failure rate † $\lambda_{SS}$	(g)						
Environmental factor $\pi_E$	(h)						
Failure rate $\lambda_G$ (g)/[(h)x(c)]	(i)						
Number of units on test $N_0$	(j)						
(1) If (e)<10,000 Enter $4 \times 10^{-6} \times (e)^{0.25}$ (2) If (e)>10,000 Enter $3 \times 10^{-6} + (e) \times 10^{-6}$	(k)						
[(2)/(i)] + (j)x(k)	(m)						
Base failure rate $\lambda_G^*$ [2 + (f)/(m)]	(n)						
Method II steady-state failure rate $\lambda_{SS}^*$ (h)x(n)x(c)	(p)						
Comments:							

‡ Obtain From Table G, Curve 7

† Obtain From Form 2

Figure 17. Unit Reliability Prediction, Case L-2 (Form 10)

Instructions for Form 11:

Worksheet for Device Reliability Prediction, Laboratory Data

Case L3: Devices Laboratory Tested with Burn-In

- [1] Provide the items of information requested on the top portion of the form.
- [2] Fill in one column of the form for each device used in the unit.
- [3] Enter the device type. The description should be sufficient to verify that the correct base failure rate was selected.
- [4] Enter the device part number.
- [5] Enter the circuit reference symbol(s).
- [6] Record the device generic failure rate ( $\lambda_{G_i}$ ). This value may be obtained from Table A. If a device is not listed in Table A, select a failure rate for a device that is most like the unlisted device. If no reasonable match can be made, use available field data, test data, or the device manufacturer's reliability estimate. Document and submit the rationale used in determining the failure rate.
- [7] Record the device quality factor  $\pi_Q$ . Obtain it from Table D.
- [8] Record the following device burn-in data:  
 $T_{b,d}$  = device burn-in temperature ( $^{\circ}\text{C}$ )  
 $A_{b,d}$  = Arrhenius acceleration factor  
(Table G, Curve 7) corresponding  
to the device burn-in temperature.  
 $t_{b,d}$  = device burn-in time (hours).
- [9] Calculate the effective burn-in time by  $(e) = (c) \times (d)$ .
- [10] Record the following laboratory test data:
  1. Laboratory test temperature ( $^{\circ}\text{C}$ )
  2. Arrhenius acceleration factor (Table G, Curve 7) corresponding to the laboratory test temperature
  3. Actual time on test (hours).
- [11] Record the number of devices on test ( $N_o$ ).
- [12] Enter the total number of laboratory failures,  $n$ .
- [13] Calculate the effective time on test, in hours, by  $(j) = (f) \times (g)$ .

- [14] Calculate the Method II device base failure rate ( $\lambda_{G_i}^*$ ) by performing the operations shown in the remaining rows.
- [15] To calculate unit steady-state failure rates from these failure rates, transcribe the device base failure rate ( $\lambda_{G_i}^*$ ) onto Form 2 or 5.

## Device Reliability Prediction Laboratory Data Worksheet

Case L3-Devices Laboratory Tested (Devices Have Had Burn-in)

Date		Page ____ Of ____					
Unit		Manufacturer					
Device name							
Part number							
Circuit ref. symbol							
Failure rate**	$\lambda_{G1}$	(a)					
Quality factor	$\pi_Q$	(b)					
Device Burn-in							
Temperature	$T_{b,d}$						
Acceleration factor ‡	$A_{b,d}$	(c)					
Time	$t_{b,d}$	(d)					
Effective burn-in time (c)x(d)	$t_e$	(e)					
Laboratory test							
Laboratory test temperature							
Test acceleration factor ‡		(f)					
Time on test		(g)					
Number of devices on test	$N_0$	(h)					
Number of lab failures	n	(i)					
Effective time on test (f)x(g)	$T_T$	(j)					
(e) + (j)		(k)					
Weighing factor W							
(1) If (k) ≤ 10,000							
(m) = (k) <sup>0.25</sup> - (e) <sup>0.25</sup>							
(2) If (k) > 10,000 and (e) ≤ 10,000							
(m) = (k)/4000 + 7.5 - (e) <sup>0.25</sup>							
(3) Otherwise, if (e) > 10,000							
(m) = (j)/4		(m)					
$[2/(e)] + 4 \times 10^{-4} \times (b) \times (h) \times (m)$		(n)					
Method II Base failure rate [2 + (i)]/(n)		$\lambda_{G1}$	(p)				
Comments:							

‡ Obtain From Table G  
\*\* Obtain From Table A

Figure 18. Device Reliability Prediction, Case L-3 (Form 11)

Instructions for Form 12:

Worksheet for Unit Reliability Prediction, Laboratory Data

Case L4: Units Laboratory Tested with Burn-In (Unit/device burn-in)

- [1] Provide the items of information requested on the top portion of the form.
- [2] Fill in one column of the form for each unit comprising the product.
- [3] Indicate the repair category by placing an (X) in the appropriate row.
- [4] Record the following device burn-in data.

$T_{b,u}$  = unit burn-in temperature (°C)

$A_{b,u}$  = Arrhenius acceleration factor (Table G, Curve 7) corresponding to the unit burn-in temperature

$t_{b,u}$  = unit burn-in time (hours). If more than one burn-in temperature is involved in unit burn-in, record the additional  $T_b$ ,  $A_b$ , and  $t_b$  values in the appropriate row. The same column may be used to record multiple sets of  $T_b$ ,  $A_b$ , and  $t_b$  data.

- [5] Calculate  $T_{b,d}^*$ , the average accelerated burn-in time of the devices in the unit, or give a close approximation.  $T_{b,d}^*$  is calculated as follows:

$$T_{b,d}^* = \left( \sum_{i=1}^{N^*} A_{b,i} t_{b,i} N_i \lambda_{G_i} \right) / \left( \sum_{i=1}^{N^*} N_i \lambda_{G_i} \right)$$

where

$A_{b,i}$  = temperature acceleration factor (from Table G, Curve 7) for the  $i^{\text{th}}$  device.

$t_{b,i}$  = burn-in time for the  $i^{\text{th}}$  device (in hours)

$N_i$  = number of devices of this type in the unit

$N^*$  = number of device types in the unit

Document and submit calculations used to determine  $T_{b,d}^*$ .

- [6] Calculate the effective burn-in time  $T_e = A_{b,u} t_{b,u} + T_{b,d}^*$ .
- [7] Record the following laboratory test data:
  - 1. Laboratory test temperature ( $^{\circ}\text{C}$ )
  - 2. Arrhenius acceleration factor (Table G, Curve 7) corresponding to the laboratory test temperature
  - 3. Actual time on test (hours).
- [8] Calculate the effective time on test ( $T_1$ ), in hours, by  $(d) = (b) \times (c)$ .
- [9] Record the number of laboratory failures,  $n$ .
- [10] Transcribe the steady-state failure rate ( $\lambda_{SS}$ ) from Form 4 or 6.
- [11] Determine the temperature acceleration factor at normal operating temperature from Table G.
- [12] Enter the environmental factor  $\pi_E$  from Form 1.
- [13] Determine the failure rate  $\lambda_G$  by  $(f) / \{(g) \times (h)\}$ .
- [14] Record the number of units on test ( $N_o$ ).
- [15] Perform the calculations indicated in the remaining rows to determine the Method II steady-state failure rate ( $\lambda_{SS}$ ). To calculate Method II predictions on unit failure rates, substitute  $\lambda_{SS}$  onto Form 3, 4, or 6, whichever is preferred.

# Unit Reliability Prediction Laboratory Data Worksheet

Case L4-Units Laboratory Tested (Units/Devices Have Had Burn-in)

Date		Page ____ Of ____	
Product	Rev	Manufacturer	

  

Unit name							
Unit number							
Repair category							
Factory repairable							
Field repairable							
Other							
Unit Burn-in							
Temperature $T_{b,u}$							
Acceleration factor $\ddagger A_{b,u}$							
Time $t_{b,u}$							
Device burn-in $T_{b,d}$							
Effective burn-in time $A_{b,u} t_{b,u} + T_{b,d}$	$t_e$	(a)					
Laboratory test							
Temperature							
Acceleration factor $\ddagger A_L$		(b)					
Time on test $T_a$		(c)					
Effective time on test (b)x(c)	$T_T$	(d)					
Number of lab failures $n$		(e)					
Steady-state failure rate $\lambda_{SS}$		(f)					
Temperature factor $\ddagger$		(g)					
Environmental factor $\pi_E$		(h)					
Failure rate (f)/[(g)x(h)]	$\lambda_G$	(i)					
Number of units on test $N_0$		(j)					
Enter $4 \times 10^{-4}$		(k)					
(a) + (d)		(l)					
(1) If (l) < 10,000 Enter (l) <sup>0.25</sup> - (a) <sup>0.25</sup> (2) If (l) > 10,000 and (a) ≤ 10,000 Enter (l)/4000 + 7.5 - (a) <sup>0.25</sup> (3) Otherwise, if (a) > 10,000 Enter (d)/4	W	(m)					
2/(l) + (j)x(k)x(m)		(n)					
Base failure rate [2 + (e)]/(a)	$\lambda^*G$	(p)					
Method II steady-state failure rate (h)x(p)x(q)	$\lambda_{SS}$						

$\ddagger$  Obtain From Table G, Curve 7

ADDITIONAL RELIABILITY DATA REPORT

System \_\_\_\_\_ Date \_\_\_\_\_  
Manufacturer \_\_\_\_\_

A. Describe design controls and standards imposed on this system that enhance its reliability.

B. Present results of operational reliability studies, describe burn-in procedures, etc.

C. Describe maintenance aspects of system design as they relate to reliability.

Figure 20. Additional Reliability Data Report (Form 13)

LIST OF SUPPORTING DOCUMENTS

System \_\_\_\_\_ Date \_\_\_\_\_

Manufacturer \_\_\_\_\_



Figure 21. List of Supporting Documents (Form 14)

Table A. Device Failure Rates\* (Sheet 1 of 8)

DEVICE TYPE	BIPOLAR		NMOS		CMOS	
	FAILURE RATE†	TEMP STRESS CURVE	FAILURE RATE†	TEMP STRESS CURVE	FAILURE RATE†	TEMP STRESS CURVE
<b>INTEGRATED CIRCUITS DIGITAL</b>						
1-20 GATES**	36	5	69	8	40	8
21-50	38	6	74	8	42	8
51-100	40	6	82	8	44	8
101-500	51	6	110	8	52	8
501-1000	63	6	150	8	61	8
1001-2000	75	6	190	8	70	8
2001-3000	85	6	230	8	77	8
3001-5000	97	6	270	8	84	8
5001-7500	110	6	320	8	92	8
7501-10000	120	6	360	8	99	8
10001-15000	130	6	420	8	110	8
15001-20000	150	6	470	8	120	8
<b>MICROPROCESSORS</b>						
1-20 GATES	16	5	60	8	32	8
21-50	17	6	65	8	33	8
51-100	18	6	71	8	35	8
101-500	22	6	98	8	40	8
501-1000	27	6	130	8	45	8
1001-2000	32	6	160	8	50	8
2001-3000	36	6	190	8	55	8
3001-5000	40	6	230	8	59	8
5001-7500	45	6	270	8	64	8
7501-10000	49	6	310	8	67	8
10001-15000	53	6	350	8	71	8
15001-20000	58	6	400	8	75	8
20000-30000	64	6	450	8	80	8

DEVICE TYPE	FAILURE RATE†	TEMP STRESS CURVE
<b>LINEAR</b>		
1-32 TRANSISTORS	27	9
33-90	54	9
91-170	80	9
171-260	100	9
261-360	130	9
361-470	150	9
471-590	170	9
591-720	190	9
721-860	210	9
<b>HYBRID MICROCIRCUIT</b>	See Table B	

\* Table values that are changed for this issue are in **boldface**. Note that all Integrated Circuit failure-rates in Table A are reported at Quality Level II and separate Quality Factors are to be applied to distinguish hermetic and non-hermetic. (See Table D.)

† FAILURES IN  $10^9$  HOURS

\*\* The number of gates is equal to the number of logical gates on the device schematic.

Table A. Device Failure Rates\* (Sheet 2 of 8)

DEVICE TYPE	BIPOLAR		NMOS		CMOS		
	FAILURE RATE†	TEMP STRESS CURVE	FAILURE RATE†	TEMP STRESS CURVE	FAILURE RATE†	TEMP STRESS CURVE	
RANDOM ACCESS MEMORY		STATIC		STATIC			
Range	Nominal						
1-320 BITS	256 BITS	22	7	21	9	22	9
421-576	512	27	7	25	9	26	9
577-1120	1K†	34	7	31	9	33	9
1121-2240	2K	45	7	40	9	42	9
2241-5000	4K	61	6	52	9	54	9
5001-11000	8K	83	6	70	9	72	9
11001-17000	16K	110	6	93	9	95	9
17001-38000	32K	160	6	120	9	130	9
38001-74000	64K	220	6	170	8	170	8
74001-150,000	128K	300	6	220	8	220	8
150,001-300,000	256K	420	6	300	8	300	8
				DYNAMIC			
1-320 BITS	256 BITS			26	9		
321-576	512			30	9		
577-1120	1K			35	9		
1121-2240	2K			42	9		
2241-5000	4K			51	9		
5001-11000	8K			62	9		
11001-17000	16K			76	9		
17001-38000	32K			94	9		
38001-74000	64K			120	8		
74001-150,000	128K			140	8		
150,001-300,000	256K			180	8		
300,001-600,000	512K			220	8		
600,001-1,200,000	1024K			270	8		

#### GATE ARRAYS, PROGRAM ARRAY LOGIC (PAL)

1. Determine the number of gates being used for the digital portion of the circuit.
2. Determine the number of transistors being used for the analog portion of the circuit (if any).
3. Look up the base failure rates for a digital IC and linear device using the number of gates and transistors determined in Steps 1 and 2.
4. Sum the failure rates determined in Step 3.

Temperature stress curve: the curve listed for a digital IC with the number of gates determined in Step 1.

\* Table values that are changed for this issue are in **boldface**. Note that all Integrated Circuit failure rates in Table A are reported at Quality Level II and separate Quality Factors are to be applied to distinguish hermetic and non-hermetic. (See Table D.)

† FAILURES IN 10<sup>9</sup> HOURS

‡ K equals 1024 BITS.

Table A. Device Failure Rates\* (Sheet 3 of 8)

DEVICE TYPE		BIPOLAR		NMOS		CMOS	
		FAILURE RATE†	TEMP STRESS CURVE	FAILURE RATE†	TEMP STRESS CURVE	FAILURE RATE†	TEMP STRESS CURVE
ROMS, PROMS, EPROMS							
Range	Nominal						
1-320 BITS	256 BITS	6	6	13	9	15	9
321-576	512	7	6	14	9	17	9
577-1120	1K‡	9	6	16	9	19	9
1121-2240	2K	13	6	19	9	22	9
2241-5000	4K	20	6	22	9	27	9
5001-11000	8K	32	6	26	9	32	9
11001-17000	16K	54	6	30	9	38	9
17001-38000	32K	93	6	35	9	46	9
38001-74000	64K	160	6	42	10	55	10
74001-150,000	128K	290	6	49	10	67	10
150,001-300,000	256K	500	6	58	10	81	10
300,001-600,000	512K	860	6	68	10	97	10
600,001-1,200,000	1024K	1500	6	81	10	120	10

\* Table values that are changed for this issue are in **boldface**. Note that all Integrated Circuit failure rates in Table A are reported at Quality Level II and separate Quality Factors are to be applied to distinguish hermetic and non-hermetic. (See Table D.)

† FAILURES IN  $10^9$  HOURS

‡ K equals 1024 BITS.

Table A. Device Failure Rates\* (Sheet 4 of 8)

DEVICE TYPE	FAILURE RATE†	TEMP STRESS CURVE	NOTES
<b>OPTO-ELECTRONIC DEVICES</b>			
<b>FIBER OPTIC TRANSMITTERS</b>			
Laser Diode			
850 nm‡	15000	10	See Note A below
1300 nm	5000	10	See Note A below
1550 nm	5000	10	See Note A below
LED			
850 nm	2000	10	See Note A below
1300 nm	200	10	See Note A below
1550 nm	200	10	See Note A below
<b>FIBER OPTIC DETECTORS</b>			
Si PIN PD	2	10	See Note A below
Si APD	20	10	See Note A below
Ge PIN PD	20	10	See Note A below
Ge APD	200	10	See Note A below
Other PIN** PDs	400	10	See Note A below
Other APDs	800	10	See Note A below
<b>GENERAL PURPOSE</b>			
Single LED	15	10	
Phototransistor	65	10	
Photodiode	15	10	
<b>SINGLE ISOLATORS</b>			
PHOTODIODE DETECTOR	15	10	
PHOTOTRANSISTOR DETECTOR	115	10	
LIGHT SENSITIVE RESISTOR	50	10	
<b>DUAL ISOLATORS</b>			
PHOTODIODE DETECTOR	30	10	
PHOTOTRANSISTOR DETECTOR	320	10	
LIGHT SENSITIVE RESISTOR	170	10	
<b>ALPHA-NUMERIC DISPLAYS</b>			
1 CHARACTER	20	10	
1 CHARACTER W/LOGIC CHIP	30	10	
2 CHARACTER	30	10	
2 CHARACTER W/LOGIC CHIP	40	10	
3 CHARACTER	40	10	
3 CHARACTER W/LOGIC CHIP	50	10	
4 CHARACTER	45	10	
5 CHARACTER	50	10	
6 CHARACTER	50	10	
7 CHARACTER	55	10	
8 CHARACTER	60	10	
9 CHARACTER	65	10	
10 CHARACTER	70	10	

**Note A:** Only hermetic, Quality Level III fiber-optic devices should be used for major network products. Non-hermetic or lower quality parts are expected to have much higher failure rates than would be predicted by using Table D device quality factors. Also, significant differences in failure rates of these devices are expected among different suppliers. Bellcore recommends that field data and/or laboratory data be used to support reliability predictions for these devices, and that additional questions be directed to the Bellcore Component Reliability District.

\* Table values in **boldface** are new or revised in this issue of the RPP.

† FAILURES IN  $10^9$  HOURS.

‡ nanometers

\*\* "Other" refers to III-V or quaternary heterostructure types of photodetectors.

Table A. Device Failure Rates\* (Sheet 5 of 8)

DEVICE TYPE	FAILURE RATE†	TEMP STRESS CURVE	ELEC STRESS CURVE(S)	NOTES
<b>TRANSISTORS</b>				
<b>SILICON</b>				
NPN				
≤0.6 W	18	4	E, E**	
0.6-60 W	25	4	E, E**	
>60 W	45	4	E, E**	
PNP				
≤0.6 W	25	4	E, E**	
0.6-60 W	40	4	E, E**	
>60 W	70	4	E, E**	
<b>GERMANIUM</b>				
NPN				
≤0.6 W	60	4	E, E**	
0.6-60 W	90	4	E, E**	
>60 W	150	4	E, E**	
PNP				
≤0.6 W	20	4	E	
0.6-60 W	30	4	E	
>60 W	55	4	E	
<b>FIELD EFFECT TRANSISTOR (FET)</b>				
<b>SILICON</b>				
LINEAR	50	4	E	
SWITCH	25	4	E	
HIGH FREQUENCY	175	4	E	
<b>GaAs</b>				
LOW NOISE (≤100 mW)	100	4	E	
DRIVER (≤100 mW)	720	4	E	
<b>UNIJUNCTION</b>	180	4	E	
<b>MICROWAVE</b>				
PULSE AMPLIFIER	1200			
CONTINUOUS WAVE	2400			
<b>DIODES</b>				
<b>SILICON</b>				
GENERAL PURPOSE				
<1 AMP	10	4	F, K†	
1 - 20 AMP	10	4	F, K†	
>20 AMP	10	4	F, K†	
MICROWAVE DETECTOR	100	3	F	
MICROWAVE MIXER	150	3	F	
<b>GERMANIUM</b>				
GENERAL PURPOSE				
<1 AMP	12	8	F, K†	
1 - 20 AMP	30	8	F, K†	
>20 AMP	120	8	F, K†	
MICROWAVE DETECTOR	280	8	F	
MICROWAVE MIXER	500	8	F	
VOLTAGE REGULATOR	3	3	E	
ZENER AND AVALANCHE	4.5	3	E	
<b>THYRISTOR</b>				
<1 AMP	19	4	F	
>1 AMP	62	4	F	
<b>VARACTOR, STEP RECOVERY, TUNNEL</b>	57	3		
<b>VARISTOR, SILICON CARBIDE</b>	10			

\* Table values in boldface are new or revised in this issue of the RPP.

† FAILURES IN  $10^9$  HOURS

\*\* First curve is ( $P_{operate}/P_{rated}$ ). Second curve is ( $V_{ce,operate}/V_{ce,rated}$ ).

‡ First curve is ( $I_{operate}/I_{rated}$ ). Second curve is ( $V_{r,operate}/V_{r,rated}$ ).

Table A. Device Failure Rates\* (Sheet 6 of 8)

DEVICE TYPE	FAILURE RATE†	TEMP STRESS CURVE	ELEC STRESS CURVE	NOTES
THERMISTOR				
BEAD	4			
DISK	13			
ROD	20			
RESISTORS, DISCRETE				
FIXED				
CHIP	0.4			
COMPOSITION				
<1 MEGOHM	4	6	D	
>1 MEGOHM	8	6	D	
FILM				
<1 MEGOHM	2	3	C	
>1 MEGOHM	3	3	C	
FILM, POWER				
<1 MEGOHM	5	1	A	
>1 MEGOHM	14	1	A	
NETWORKS (PER RESISTOR)	1.3	6		
WIREWOUND, ACCURATE				
<1 MEGOHM	33	2	C	
>1 MEGOHM	86	2	C	
WIREWOUND, POWER, LEAD MOUNTED	56	3	D	
WIREWOUND, POWER, CHASSIS MOUNTED	30	3	D	
VARIABLE				
NON-WIREWOUND				
FILM				
<200K OHM	50	3	B	
>200K OHM	80	3	B	
LOW PRECISION, CARBON				
<200K OHM	70	4	B	
>200K OHM	100	4	B	
PRECISION				
<200K OHM	50	4	A	
>200K OHM	75	4	A	
TRIMMER				
<200K OHM	50	2	A	
>200K OHM	75	2	A	
WIREWOUND				
HIGH POWER, ENCLOSED				
<5K OHM	340	3	B	
>5K OHM	480	3	B	
HIGH POWER, UNENCLOSED				
<5K OHM	160	3	B	
>5K OHM	240	3	B	
LEADSCREW	50	3	C	
PRECISION				
<100K OHM	420	3	A	
>100K OHM	740	3	A	
SEMI-PRECISION				
<5K OHM	180	4	C	
>5K OHM	260	4	C	
THICK OR THIN FILM RESISTOR NETWORK	0.5			PER RESISTOR

\* Table values in **boldface** are new or revised in this issue of the RPP.

† FAILURES IN  $10^9$  HOURS

Table A. Device Failure Rates\* (Sheet 7 of 8)

DEVICE TYPE	FAILURE RATE†	TEMP STRESS CURVE	ELEC STRESS CURVE(S)	NOTES
<b>CAPACITORS, DISCRETE</b>				
FIXED				
MOS OR CHIP	3			
PAPER	15	2	J	
PAPER/PLASTIC	25	2	J	
PLASTIC	5	3	J	
MICA	3	7	G	
GLASS	2	7	G	
CERAMIC	3	1	H	
TANTALUM, SOLID, SEALED	6	3	G	
TANTALUM, NONSOLID	14	3	G	
ALUMINUM, AXIAL LEAD				
< 400 $\mu$ f	30	7	E	
400 $\mu$ f-12000 $\mu$ f	54	7	E	
> 12000 $\mu$ f	83	7	E	
ALUMINUM, CHASSIS MOUNTED				
< 400 $\mu$ f	41	7	E	
400-12000 $\mu$ f	76	7	E	
> 12000 $\mu$ f	110	7	E	
<b>VARIABLE</b>				
AIR, TRIMMER	20	5	H	
CERAMIC	15	3	J	
PISTON, GLASS	5	5	H	
VACUUM	50	2	I	
<b>CAPACITOR NETWORK</b>				SUM INDIVIDUAL CAPACITOR FAILURE RATES
<b>INDUCTIVE DEVICES</b>				
TRANSFORMER				
PULSE LOW LEVEL	4	3		
PULSE HIGH LEVEL	19	3		
AUDIO	7	3		
POWER	19	3		
RADIO FREQUENCY	30	3		
COIL				
LOAD COIL	7	3		
POWER FILTER	19	3		
RADIO FREQUENCY, FIXED	0.5	3		
RADIO FREQUENCY, VARIABLE	1	3		
<b>CONNECTORS</b>				
GENERAL	5			PER PIN
PRINTED WIRING BOARD EDGE	0.4			PER PIN
IC SOCKET	0.2			PER PIN
<b>SWITCHES†</b>				
TOGGLE PUSHBUTTON, ROCKER, SLIDE	10		C	BODY PLUS 5 PER CONTACT PAIR
SENSITIVE	20		C	BODY PLUS 5 PER CONTACT PAIR
ROTARY	30		C	BODY PLUS 5 PER CONTACT PAIR
SCREW	5			PER SCREW
<b>RELAYS</b>				
GENERAL PURPOSE	140	3	C	
CONTACTOR	560	3	C	
LATCHING	140	3	C	
REED	160	3	C	
THERMAL, BIMETAL	280	3	C	
METER, MOVEMENT	930	3	C	
MERCURY	280	3	C	
<b>ROTATING DEVICES**</b>				
BLOWERS, FAN	2000			
MOTORS	500			

\* Table values in **boldface** are new or revised in this issue of the RPP.

\*\* Derived from MIL-HDBK-217B.

† FAILURES IN  $10^9$  HOURS

‡ The number of contact pairs equals  $n \times 2^{m-1}$ , where  $n$  equals the number of poles and  $m$  equals the number of throws. For example, a single pole double throw (SPDT) switch has  $1 \times 2^1 = 2$  contact pairs.

Table A. Device Failure Rates\* (Sheet 8 of 8)

DEVICE TYPE	FAILURE RATE†	NOTES
MISCELLANEOUS DEVICES		
GYROSCOPE**	50,000	
VIBRATOR		
60 HERTZ	15,000	
120 HERTZ	20,000	
400 HERTZ	40,000	
QUARTZ CRYSTAL	50	
CIRCUIT BREAKER		
Protection-Only Application	170	per pole
Power On/Off Application	1700	per pole
FUSE	10	
LAMP		
NEON	200	
INCANDESCENT		
5V DC	1400	
12V DC	4300	
METER	300	
HEATER (CRYSTAL OVEN)**	1,000	
MICROWAVE ELEMENTS		
COAXIAL AND WAVEGUIDE		
LOAD	15	
ATTENUATOR		
FIXED	10	
VARIABLE	10	
FIXED ELEMENTS		
DIRECTIONAL COUPLERS	10	
FIXED STUBS	10	
CAVITIES	10	
VARIABLE ELEMENTS		
TUNED STUBS	100	
TUNED CAVITIES	100	
FERRITE DEVICES (TRANSMIT)	200	
FERRITE DEVICES (RECEIVE)	100	
COOLER (TEC) <2 W	1300	

\* DERIVED FROM MIL-HDBK-217D AND 217E.

† FAILURES IN 10<sup>9</sup> HOURS

\*\* DERIVED FROM MIL-HDBK-217B, TABLE 2.13-1, REVISED SEPTEMBER 1976.

Table B. Hybrid Microcircuit Failure Rate Determination\* (Sheet 1 of 2)

Hybrid microcircuits are nonstandard and their complexity cannot be determined from their names or functions. To predict failure rates for these devices, use the procedure described in this table.

The Hybrid Failure rate model is:

$$\lambda_{HIC} = \sum (\lambda_G \pi_Q \pi_S \pi_T) + (N_I \lambda_I + N_C \lambda_C + N_R \lambda_R) (\pi_F).$$

where:

- $\lambda_G$  = device failure rate for each chip or packaged device used†
- $\pi_Q$  = quality factor
- $\pi_S$  = stress factor
- $\pi_T$  = temperature factor
- $N_I$  = number of internal interconnects (i.e., crossovers, excluding any device leads or external HIC package leads)\*\*
- $\lambda_I$  = 0.8
- $N_C$  = number of thin or thick film capacitors
- $\lambda_C$  = 0.5
- $N_R$  = number of thin or thick film resistors
- $\lambda_R$  = 0.2
- $\pi_F$  = circuit function factor - 1.0 for digital HICs, 1.25 for linear or linear-digital HICs

When Forms 2 and 3, or 2 and 4 are used to record reliability data for the unit in which the HIC is located:

1. Calculate the HIC failure rate on a separate sheet of paper. Show all details.
2. On Form 2, record the HIC identifying data and enter the HIC failure rate in column (f).

When Forms 5 and 6 are used to record reliability data for the unit in which the HIC is located:

1. Calculate the HIC failure rate on a separate sheet of paper. Show all details.
2. On Form 5, record the HIC identifying data and enter the quantity of the particular HIC times the HIC failure rate in row (f).

\* This is a modified version of the procedure specified in MIL-HDBK-217.

† In Table A, no distinction is made between semiconductor chips and packaged devices. For semiconductors: when chips are used - if HIC is Hermetic, use Hermetic device failure rate and quality level. If HIC is non-Hermetic, use non-Hermetic device failure rate and quality level. When packaged devices are used - ignore HIC packaging and use appropriate Hermetic (non-Hermetic) device failure rate and quality level.

\*\* If HIC includes any type of connector, the connector should be considered as an attached component.

Table B. Hybrid Microcircuit Failure Rate Detection (Sheet 2 of 2)

3. To get credit for HIC and/or unit burn-in as it affects Infant Mortality of the HIC, complete the operations as shown in Form 5. The product of  $\pi_S \pi_T$  shall be determined by  $\lambda_{HIC}/\lambda_{HIC_{BB}}$

where:

$\lambda_{HIC_{BB}}$  = HIC failure rate when  $\pi_S$  and  $\pi_T$  are set equal to 1.0 for all devices in the HIC.

If devices comprising a HIC are burned in on a device level, the reliability calculations become more complicated. Since this condition is seldom expected to occur, no provision has been made for it in these instructions. For further assistance in this regard, contact the requesting organization.

Table C. Device Quality Level Description (Sheet 1 of 2)

The device failure rates contained in this document reflect the expected reliability performance of generic device types. The actual reliability of a specific device will vary as a function of the degree of effort and attention paid by an equipment manufacturer to factors such as device selection/application, supplier selection/control, electrical/mechanical design margins, equipment manufacture process control, and quality program requirements.

The quality levels described below are not intended to characterize or quantify all of the factors that may influence device reliability. They provide an indication of the total effort an equipment manufacturer considers reasonable to expend to control these factors.

#### QUALITY LEVEL I

This level shall be assigned to commercial-grade devices that are procured and used without thorough device qualification or lot-to-lot controls by the equipment supplier. However, (a) steps must have been taken to ensure that the components are compatible with the design application and manufacturing process; and (b) an effective feedback and corrective action program must be in place to identify and resolve problems quickly in manufacture and in the field.

#### QUALITY LEVEL II

This level shall be assigned to devices that meet requirements (a) and (b) of Quality Level I, plus the following: (c) purchase specifications must explicitly identify important characteristics (electrical, mechanical, and optical) and acceptable quality (AQL) for lot control; (d) devices and vendors must be qualified and identified on approved parts/vendor lists (device qualification must include appropriate life and endurance tests); (e) lot-to-lot controls must be in place at adequate AQLs to ensure consistent quality.

#### QUALITY LEVEL III

This level shall be assigned to devices that meet requirements (a) through (e) of Quality Levels I and II, plus the following: (f) devices must be requalified periodically; (g) lot-to-lot controls must include 100 percent screening (temperature cycling and burn-in) which, if the results warrant it, may be reduced to a "reliability audit" (i.e., on a sample basis); (h) where screening is used, the percent defective allowed (PDA) should be specified; and (i) an ongoing, continuous reliability improvement program must be implemented.

Table C. Device Quality Level Description (Sheet 2 of 2)

**Level III Test/Inspection References**

In case of any question regarding the proper assignment of Level III, the following practices should serve as guidelines for the types of test requirements that are to be satisfied.

<i>Device</i>	<i>Screen</i>	<i>Acceptance/Incoming Test</i>
Integrated Circuit	MIL-STD-883, Method 5004 Class B	MIL-STD-883, Method 5005, Class B
Transistor, Diode	MIL-S-19500, (JANTX) (except power burn-in)	MIL-S-19500 (JAN)
Capacitor (typical)	MIL-C-39014	MIL-C-39014
Resistor (typical)	MIL-R-55182	MIL-R-55182
Relay (typical)	MIL-R-39016	MIL-R-39016
Connector (typical)	MIL-C-21097	MIL-C-21097

**NOTE:** It is the manufacturer's responsibility to provide justification for all levels other than Level I. For more on reliability assurance practices, see *Component Reliability Assurance Requirements for Telecommunications Equipment*, TR-TSY-000357.<sup>[5]</sup>

TR-TSY-000357 also includes discussion of alternative types of reliability assurance practices, such as ship-to-stock verses incoming inspection.

Table D. Device Quality Factors ( $\pi_Q$ )†

QUALITY LEVEL*	INTEGRATED CIRCUITS		DISCRETE SEMICONDUCTOR DEVICES		ALL OTHER DEVICES
	HERMETIC	NON-HERMETIC	HERMETIC	PLASTIC	
I	1.5	1.8	1.5	1.8	1.5
II	1.0	1.0	1.0	1.0	1.0
III	0.5	0.5	0.5	0.5	0.5

1

2

3

4

5

6

† To be used only in conjunction with failure rates contained in this document.  
\* See Table C for definition of quality levels.

Table E. Guidelines for Determination of Stress Levels

The stress factors shown in Table F vary as a function of the effect of electrical stress on the various types of devices and on the amount of stress encountered in any particular application. If, during normal operation of the end product in which the device is used, the amount of stress varies, determine the average stress.

Table A describes the appropriate curve to use for each type of device. If no curve number is shown, the  $\pi_s$  factor may be considered to be 1.0.

These stress curves apply to the following rating characteristics:

Capacitor	- Sum of applied dc voltage plus ac peak voltage/rated voltage
Resistor, fixed	- applied power/rated power
Resistor, variable	- ( $V_{in}^2$ /total resistance)/rated power
Relay, Switch	- Contact current/rated current (rating appropriate for type of load, e.g., resistive, inductive, lamp)
Diode, general purpose, Thyristor	- average forward current/rated forward current
Diode, zener	- zener current or power/rated zener current or power
Varactor, Step recovery, Tunnel diode	- Power dissipated/rated power
Transistor	- Power dissipated/rated power.

Note: "Rated" as used here refers to the maximum or minimum value specified by the manufacturer (after any derating for temperature, etc.)

Table F. Stress Factors ( $\pi_S$ )

% STRESS	Electrical Stress Curve:										
	A	B	C	D	E	F	G	H	I	J	K
10	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.2	0.2	0.1	1.0
20	0.8	0.8	0.7	0.6	0.5	0.4	0.3	0.3	0.3	0.2	1.0
30	0.9	0.8	0.8	0.7	0.6	0.6	0.5	0.4	0.4	0.3	1.0
40	0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.6	0.6	1.0
50	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
60	1.1	1.1	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.8	1.1
70	1.1	1.2	1.3	1.5	1.6	1.8	2.0	2.3	2.5	3.3	1.1
80	1.2	1.3	1.5	1.8	2.1	2.4	2.9	3.4	4.0	5.9	1.2
90	1.3	1.4	1.7	2.1	2.6	3.2	4.1	5.2	6.3	10.6	1.3

1 2 3 4 5 6 7 8 9 10 11 12

Table G. Temperature Factors ( $\pi_T$ ) (Sheet 1 of 2)

For long-term failure rates, refer to Table A to determine the appropriate temperature stress curve.

TEMPERATURE FACTORS ( $\pi_T$ )										
Operating Temperature† °C	Temperature Stress Curve									
	1	2	3	4	5	6	7	8	9	10
30	1.0	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.4
31	1.0	0.9	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5
32	1.0	0.9	0.9	0.8	0.8	0.7	0.6	0.6	0.6	0.5
33	1.0	0.9	0.9	0.9	0.8	0.7	0.7	0.7	0.6	0.6
34	1.0	0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.7	0.6
35	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.8	0.7	0.7
36	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.7
37	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.8	0.8
38	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.8
39	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9
40	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
41	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1
42	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.2
43	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3
44	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.4
45	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.5
46	1.0	1.1	1.1	1.1	1.2	1.3	1.3	1.4	1.5	1.6
47	1.0	1.1	1.1	1.2	1.3	1.3	1.4	1.4	1.6	1.8
48	1.0	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.7	1.9
49	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.6	1.8	2.1
50	1.0	1.1	1.1	1.2	1.4	1.5	1.6	1.7	1.9	2.2
51	1.0	1.1	1.2	1.3	1.4	1.6	1.7	1.8	2.0	2.4
52	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2.2	2.6
53	1.0	1.1	1.2	1.3	1.5	1.7	1.8	1.9	2.3	2.8
54	1.0	1.1	1.2	1.4	1.6	1.7	1.9	2.0	2.4	3.0
55	1.0	1.1	1.2	1.4	1.6	1.8	2.0	2.1	2.6	3.3
56	1.0	1.2	1.2	1.4	1.7	1.9	2.1	2.3	2.8	3.5
57	1.0	1.2	1.3	1.4	1.7	2.0	2.2	2.4	2.9	3.8
58	1.1	1.2	1.3	1.5	1.8	2.0	2.2	2.5	3.1	4.1
59	1.1	1.2	1.3	1.5	1.8	2.1	2.3	2.6	3.3	4.4

† The unit operating temperature is determined by placing a temperature probe in the air ¼ inch above (or between) the unit(s) while they are operating under normal conditions. The device operating temperature is the unit operating temperature of the unit in which the device resides.

Table G. Temperature Factors ( $\pi_T$ ) (Sheet 2 of 2)

TEMPERATURE FACTORS ( $\pi_T$ )										
Operating Temperature† °C	Temperature Stress Curve									
	1	2	3	4	5	6	7	8	9	10
60	1.1	1.2	1.3	1.5	1.9	2.2	2.4	2.7	3.5	4.8
61	1.1	1.2	1.3	1.6	1.9	2.3	2.5	2.9	3.7	5.1
62	1.1	1.2	1.3	1.6	2.0	2.3	2.7	3.0	3.9	5.5
63	1.1	1.2	1.4	1.6	2.0	2.4	2.8	3.1	4.2	5.9
64	1.1	1.2	1.4	1.7	2.1	2.5	2.9	3.3	4.4	6.4
65	1.1	1.2	1.4	1.7	2.2	2.6	3.0	3.4	4.7	6.8
70							3.7			
75							4.5			
80							5.4			
85							6.5			
90							7.7			
95							9.2			
100							11			
105							13			
110							15			
115							18			
120							21			
125							24			
130							28			
135							32			
140							37			
145							42			
150							48			

† The unit operating temperature is determined by placing a temperature probe in the air ¼ inch above (or between) the unit(s) while they are operating under normal conditions. The device operating temperature is the unit operating temperature of the unit in which the device resides.

Table H. Environmental Conditions and Multiplying Factors ( $\pi_E$ )

ENVIRONMENT	<sup>E</sup> SYMBOL	$\pi_E$	NOMINAL ENVIRONMENTAL CONDITIONS
Ground, Benign	$G_B$	1.0	Nearly zero environmental stress with optimum engineering operation and maintenance. Typical applications are central office, environmentally controlled remote shelters, and environmentally controlled customer premise areas.
Ground, Fixed	$G_F$	1.5	Conditions less than ideal, some environmental stress, maintenance limited. Typical applications are manholes, poles, remote terminals, customer premise areas subject to shock and vibration, or temperature and atmospheric variations.
Ground, Mobile (and Portable)	$G_M$	5.0	Conditions more severe than $G_F$ , mostly for shock and vibration. More maintenance limited and susceptible to operator abuse. Typical applications are mobile telephone, portable operating equipment, and test equipment.

Table I. First Year Multiplier ( $\pi_{FY}$ )

Time (hours)	Multiplier	Time (hours)	Multiplier
0-1	4.0	600-799	2.2
2	3.9	800-999	2.1
3-4	3.8	1000-1199	2.0
5-9	3.7	1200-1399	1.9
10-14	3.6	1400-1599	1.8
15-24	3.5	1600-1999	1.7
25-34	3.4	2000-2499	1.6
35-49	3.3	2500-2999	1.5
50-69	3.2	3000-3499	1.4
70-99	3.1	3500-3999	1.3
100-149	3.0	4000-4900	1.2
150-199	2.8	5000-5999	1.2
200-249	2.7	6000-6999	1.1
250-349	2.6	7000-10000	1.0
350-399	2.5		
400-499	2.4		
500-599	2.3		

*For Case 2: Black Box option with unit/system burn-in > 1 hour, no device burn-in*

Use line (a) on Form 4 as the Time in selecting the first year multiplier from Table I.

*For Case 3: General Case*

When operating temperature and electrical stress are 40 °C and 50 percent:

Use line (p), Form 5, as the Time in selecting the first year Multiplier from Table I.

- If (p)  $\leq$  2240, then record the Multiplier on Form 5, line (s).
- If (p) > 2240, then record the Multiplier on Form 5, line (t).

When operating temperature and electrical stress are not 40 °C and 50 percent (limited stress option):

Table I cannot be used directly for calculation of the first year Multiplier. However, the first year Multiplier can be calculated from Table I multiplier values using Form 5, as follows:

- If (q)  $\leq$  (o) - 8760 from Form 5, then select the multiplier value from Table I that corresponds to the time value in line (q). Record that multiplier value on Form 5, line (s), and compute the first year Multiplier using the formula on the following line.
- If (q) > (o) - 8760 from Form 5, then select the multiplier value from Table I that corresponds to the time value in line (p). Record that multiplier value on Form 5, line (t), and compute the first year Multiplier using the formula on the following line.

Table J. Reliability Conversion Factors

FROM	TO	OPERATION
FITs*	Failures/ $10^6$ hrs.	$\text{FITs} \times 10^{-3}$
FITs	% Failures/1000 hrs.	$\text{FITs} \times 10^{-4}$
FITs	% Failures/yr. or Failures/100 units/yr.	$\text{FITs}/1142$
FITs	% Failures/mo. or Failures/100 units/mo.	$\text{FITs}/13700$
FITs	MTBF†	$\frac{10^9 \text{ hours}}{\text{FITs}}$
Failures/ $10^6$	FITs	$\text{Failures}/10^6 \text{ hrs.} \times 10^3$
% Failures/1000 hrs.	FITs	$\% \text{ Failures}/1000 \text{ hrs.} \times 10^4$
% Failures/yr. or Failures/100 units/yr.	FITs	$\% \text{ Failures}/\text{yr.} \times 1142$
% Failures/mo. or Failures/100 units/mo.	FITs	$\% \text{ Failures}/\text{mo.} \times 13,700$
MTBF	FITs	$\frac{10^9}{\text{MTBF}}$

\* Failures in  $10^9$  hours.

† Mean time (hours) between failures.

Table K. Upper 90% Confidence Limit ( $U$ ) for the Mean of a Poisson Distribution

Failure Count $f$	Upper Confidence Limit $U$	Failure Count $f$	Upper Confidence Limit $U$	Failure Count $f$	Upper Confidence Limit $U$	Failure Count $f$	Upper Confidence Limit $U$
0	3.0						
1	4.7	41	53.2	81	97.4	121	140.7
2	6.3	42	54.3	82	98.5	122	141.8
3	7.8	43	55.5	83	99.6	123	142.9
4	9.2	44	56.6	84	100.7	124	143.9
5	10.5	45	57.7	85	101.8	125	145.0
6	11.8	46	58.8	86	102.9	126	146.1
7	13.1	47	59.9	87	104.0	127	147.2
8	14.4	48	61.1	88	105.1	128	148.2
9	15.7	49	62.2	89	106.2	129	149.3
10	17.0	50	63.3	90	107.2	130	150.4
11	18.2	51	64.4	91	108.3	131	151.5
12	19.4	52	65.5	92	109.4	132	152.5
13	20.7	53	66.6	93	110.5	133	153.6
14	21.9	54	67.7	94	111.6	134	154.7
15	23.1	55	68.9	95	112.7	135	155.7
16	24.3	56	70.0	96	113.8	136	156.8
17	25.5	57	71.1	97	114.8	137	157.9
18	26.7	58	72.2	98	115.9	138	158.9
19	27.9	59	73.3	99	117.0	139	160.0
20	29.1	60	74.4	100	118.1	140	161.1
21	30.2	61	75.5	101	119.2	141	162.2
22	31.4	62	76.6	102	120.2	142	163.2
23	32.6	63	77.7	103	121.3	143	164.3
24	33.8	64	78.8	104	122.4	144	165.4
25	34.9	65	79.9	105	123.5	145	166.4
26	36.1	66	81.0	106	124.6	146	167.5
27	37.2	67	82.1	107	125.6	147	168.6
28	38.4	68	83.2	108	126.7	148	169.6
29	39.5	69	84.3	109	127.8	149	170.7
30	40.7	70	85.4	110	128.9	150	171.8
31	41.8	71	86.5	111	130.0	151	172.8
32	43.0	72	87.6	112	131.0	152	173.9
33	44.1	73	88.7	113	132.1	153	175.0
34	45.3	74	89.8	114	133.2	154	176.0
35	46.4	75	90.9	115	134.3	155	177.1
36	47.5	76	92.0	116	135.3	156	178.2
37	48.7	77	93.1	117	136.4	157	179.2
38	49.8	78	94.2	118	137.5	158	180.3
39	50.9	79	95.3	119	138.6	159	181.4
40	52.1	80	96.4	120	139.6	160	182.4



## 10. MISCELLANEOUS

$$\lambda = \dots \times 10^{-9}/h$$

Types	Basic failure rate	
	early < 300h $\lambda_e$	constant > 300h $\lambda_c$
SOLDER CONNECTIONS:		
machine	0,5	0,5
manual	5	5
PRINTED BOARDS/dm <sup>2</sup>	50	50
WIRE WRAP CONNECTIONS	0,2	0,2
CLAMP CONNECTIONS	3,5	3,5
SCART PLUGS		
COAX PLUGS/CONNECTORS	400	40
PIN CONNECTORS PER CONTACT	75	10
HIGH TENSION CABLE ASSIES	25	25
MAINS CORDS	10	10
BATTERIES rechargeable	10	100
RELAYS	1000	500
REED RELAIS	15	5
PUSH BUTTON SWITCHES	800	200
ROTARY SWITCHES	1000	250
MAINS SWITCHES	1000	1000
TEST SWITCHES	50	25
CRYSTALS	100	20
CERAMIC FILTERS	100	20
SAW FILTERS	125	25
PICTURE TUBES:		
colour	5000	1000
black/white	1000	200
FUSES	100	50
LOUDSPEAKERS	2000	500
DELAY LINES	50	50
MOTORS	3000	500
LAMPS	1500	750
TUNERS	6500	2000

Consumer  
**DSD**  
Electronics

RELIABILITY PREDICTION  
FAILURE RATES

TECHNICAL  
GROUP

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**PHILIPS**

## 9. COILS &amp; TRANSFORMERS

Types	Basic failure rate	
	early <300h $\lambda_e$	constant >300h $\lambda_c$
FIXED AND VARIABLE INDUCTORS FOR IF AND HF CIRCUITS (supplier: TDK, TOKO etc.)	10	10
ROD EARRIALS	300	100
COAX AERIAL INPUT DEVICES	100	100
DELAY COILS	100	100
LINEARITY CONTROL UNITS	100	100
SUPPRESSION COILS	100	100
CONVERGENCE COILS	100	100
DEGAUSSING COIL	25	25
SWITCH MODE TRANSFORMERS	1000	350
DEFLECTION UNITS: colour	300	150
black/white	150	75
LINE OUTPUT TRANSFORMERS: <15kV	1000	200
>15kV	2000	500
FERROXDURE TRANSFORMERS	150	50
IRON-CORE TRANSFORMERS	1000	400
VARIOUS TRANSFORMERS	300	100
LINE DRIVE TRANSFORMERS	under investigation	

$$\lambda = \dots \times 10^{-9}/h$$

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